MAKERS OF MODERN SCIENCE

WERNHER VON BRAUN

Rocket Visionary

REVISED EDITION

RAY SPANGENBURG AND DIANE KIT MOSER

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WERNHER VON BRAUN: Rocket Visionary, Revised Edition

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For all scientists, both sung and unsung,
who, in the words of Carl Sagan,
have spent their lives lighting
"candles in the dark"

CONTENTS

	Preface	xi
	Acknowledgments	xv
	Introduction	xvii
1	**Runaway Rockets, Stars, and Space**	**1**
	Early Musical Talent	1
	1920s Berlin	2
	Wellspring of Science	4
2	**Beyond Earth's Atmosphere**	**9**
	Rocket Weapons in Eighteenth-Century Warfare	10
	How Do Rockets Work?	11
	Rockets That Reach Out to Space	13
	Robert Goddard: Pioneer Rocketeer	14
	Hermann Oberth	15
3	**"Help Create the Spaceship!"**	**17**
	Cutting-Edge Amateur Rocketry	18
	Willy Ley (1906–1969): The VfR Voice	19
	Space Travel at the Movies	21
	The VfR Keeps Advancing	24
	Experiments: Can Humans Survive Space Travel?	25
4	**Rocket Engineer for the German Army**	**29**
	Dornberger's Agenda	30
	Spotty Results, Stellar Know-how	31
	Opportunity Knocks	33
	Building and Testing Real Rockets	34

Growth of Nazi Power 39
Airplanes Powered by Rockets 40

5 **Grazing the Edges of Space 43**
The Case for Peenemünde 45
A-3: High Hopes Frustrated 47
A-4: Even Higher 48
Hitler Visits 52
Adolf Hitler: Monster Unleashed 52
A "Secret Weapon" for War 54

6 **Peenemünde's Last Days 59**
Night of Fire 60
Setbacks for the A-4 Rocket 62
Production and Secrecy Mount 64
Horrors at Mittelwerke Factory 65
Dreaded Knock in the Night 67
Bigger and Better Rockets 69
Von Braun's Conscience 70

7 **Operation Paperclip 73**
Darkening Dangers from Within 74
Chess Game with Fate 75
Seeking Capture 78
Initiating "Paperclip" 79
Walter Dornberger's Deal 80

8 **V-2s in the United States 81**
The Rocket Team Arrives 83
Family Roots 85
Paperclip: Wise or Unwise? 86
Building V-2s in White Sands 88
Passports to the Future 90

9 **Prophet of the Space Age 93**
Raising Public Interest: *Collier's* Magazine 95

Enter Walt Disney 97
I Aim at the Stars 98

10 **Huntsville Becomes Rocket City 101**
Sputnik: The Space Race Is On 101
Waiting on the Back Burner 102
At Home in Alabama 103
"The Team" at Work 103
Vanguard's Day 105
The Team's Success 107

11 ***Sputnik* and the Spotlight on Space 109**
The Next Move 110
Going to the Moon 110

12 **Success: *Saturn* Soars and the *Eagle* Lands 115**
The Job: Design, Build, Test 115
Saturn: Rocket Giant 118
Redundancy: Making Sure 120
Going to the Moon: The Reality, *Apollo 11* 121

13 **Next Stop, Mars? 125**
Washington, D.C.: A Cool Welcome 126
Voyage to Mars: Unfulfilled Vision 127
Paine: An Ally Lost 128
Final Days: Spirited to the Last 130

14 **Wernher von Braun's Gift 133**

Conclusion: Weighing Human Tragedy 137

Chronology 141
Glossary 145
Further Resources 149
Index 157

PREFACE

Science is, above all, a great human adventure. It is the process of exploring what Albert Einstein called the "magnificent structure" of nature using observation, experience, and logic. Science comprises the best methods known to humankind for finding reliable answers about the unknown. With these tools, scientists probe the great mysteries of the universe—from black holes and star nurseries to deep-sea hydrothermal vents (and extremophile organisms that survive high temperatures to live in them); from faraway galaxies to subatomic particles such as quarks and antiquarks; from signs of life on other worlds to microorganisms such as bacteria and viruses here on Earth; from how a vaccine works to protect a child from disease to the DNA, genes, and enzymes that control traits and processes from the color of a boy's hair to how he metabolizes sugar.

Some people think that science is rigid and static, a dusty, musty set of facts and statistics to memorize for a test and then forget. Some think of science as antihuman—devoid of poetry, art, and a sense of mystery. Yet science is based on a sense of wonder and is all about exploring the mysteries of life and our planet and the vastness of the universe. Science offers methods for testing and reasoning that help keep us honest with ourselves. As physicist Richard Feynman once said, science is above all a way to keep from fooling yourself—or letting nature (or others) fool you. Nothing could be more growth-oriented or more human. Science evolves continually. New bits of knowledge and fresh discoveries endlessly shed new light and offer new perspectives. As a result, science is constantly undergoing revolutions—ever refocusing what scientists have explored before into fresh, new understanding. Scientists like to say science is self-correcting. That is, science is fallible, and scientists can be wrong. It is easy to fool yourself, and it is easy to be fooled by others, but

because new facts are constantly flowing in, scientists are continually refining their work to account for as many facts as possible. So science can make mistakes, but it also auto-corrects.

Sometimes, as medical scientist Jonas Salk liked to point out, good science thrives when scientists ask the right question about what they observe. "What people think of as the moment of discovery is really the discovery of the question," he once remarked.

There is no one, step-by-step "scientific method" that all scientists use. However, science requires the use of methods that are systematic, logical, and *empirical* (based on objective observation and experience). The goal of science is to explore and understand how nature works—what causes the patterns we see or experience, the shapes we find, the colors, the textures, the consistency, the mass, all the characteristics of the natural universe.

What is it like to be a scientist and actually do science? Many people think of television and movie stereotypes when they think of scientists—the cartoonlike view of the "mad" scientist or the scientist entrapped in excesses of "cold logic." In general, though, these portrayals represent more imagination than truth. Scientists know how to use their brains. They are exceptionally good with the tools of logic and critical thinking. However, that is about where the generalizations stop being accurate. Although science follows strict rules, it is often guided by the many styles and personalities of the scientists themselves, the people who *do* science—and the many faces of science also have distinct individuality, personality, and style. What better way to explore what science is all about than through the experiences of great scientists?

Each volume of the Makers of Modern Science set presents the life and lifework of a prominent scientist whose outstanding contributions in his or her field have garnered the respect and recognition of other prominent colleagues. These profiled men and women were all great scientists, but they differed in many ways. Their approaches to the use of science were different: Niels Bohr was a theoretical physicist whose strengths lay in patterns, ideas, and conceptualization, while Wernher von Braun was a hands-on scientist/engineer who led the team that built the giant rocket used by Apollo astronauts to reach the Moon. Some had genius sparked by solitary

contemplation: Geneticist Barbara McClintock worked alone in fields of maize and sometimes spoke to no one all day long. Others worked as members of large, coordinated teams. Oceanographer Robert Ballard organized oceangoing ship crews on submersible expeditions to the ocean floor; biologist Jonas Salk established the Salk Institute to help scientists in different fields collaborate more freely and study the human body through the interrelationships of their differing knowledge and approaches. Their personal styles also differed: Biologist Rita Levi-Montalcini enjoyed wearing chic dresses and makeup; McClintock was sunburned and wore baggy denim jeans and an oversize shirt; nuclear physicist Richard Feynman was a practical joker and an energetic bongo drummer.

The chosen scientists represent a spectrum of disciplines and a diversity of approaches to science as well as lifestyles. Each biography explores the scientist's younger years along with his or her education and growth as a scientist; the experiences, research, and contributions of the maturing scientist; and the course of the path to recognition. Each volume also explores the nature of science and its unique usefulness for studying the universe, as well as sidebars covering related facts or profiles of interest, introductory coverage of the scientist's field, line illustrations and photographs, a timeline, a glossary of related scientific terms, and a list of further resources including books, Web sites, periodicals, and associations.

The volumes in the Makers of Modern Science set offer a factual look at the lives and exciting contributions of the profiled scientists—in the hope that readers will see science as a uniquely human quest to understand the universe and that some readers may be inspired as well to follow in the footsteps of these great scientists.

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We would like to thank the many people who helped us with this book, including Charles Shows, Ward Kimball, and J. Clark Bullock, for their willingness to share their personal memories of Wernher von Braun. We also appreciate the energy and professionalism offered by photo researcher Suzanne M. Tibor, as well as the watchful eye of our tireless editor Frank K. Darmstadt and the encouragement of our friend and agent, Linda Allen.

INTRODUCTION

Wernher von Braun could hardly remember a time when he did not love rockets. Perhaps it all began with the telescope his mother gave him when he was a kid. He was fascinated. He wanted to go out into space and see those objects up close. At 18, he found a group of amateurs who had a passionate interest in rockets. Like him, many of them knew that rockets were the only known transportation possibility for escaping Earth's gravitational pull and reaching interplanetary space. It was an iffy hobby and an even less profitable means of support—and credentialed academics and engineers with respectable backgrounds generally frowned on rockets. Yet interest was swelling.

Rudolf Nebel, a graduate engineer, had helped found the *Verein für Raumschiffahrt* (Society for Space Travel or VfR) in 1927. He had not found work in his field in the depressed postwar economy and had no practical experience, but he and the VfR attracted a fervent band of rocket enthusiasts. By 1930, the membership of the VfR had grown to 800 members, most of them in Berlin. Physicist Hermann Oberth had come from Romania, interested in demonstrating his own rocket design. He had already written mathematical proofs showing that rockets running on liquid fuel could carry human travelers into interplanetary space, but rockets are complex, and rocket builders would run many tests that proved to go nowhere. (The director Fritz Lang planned a movie called *Frau im Mond* [Woman in the Moon], for which he hired Oberth as a consultant, as well as Willie Ley, a journalist with links to the VfR. This was just silly science fiction, but they all thought the money might be used to advantage.)

Some of the best work done in rocketry was done by these young rocketeers of the VfR. It was science fiction, but it also had real potential. Von Braun and his friends knew from their reading that they were building and testing to reach an achievable goal. Some of their

experience was nearly on a par with the work of renowned American rocketeer Robert Goddard (who also was mocked as the Moon man).

All this was just the beginning for Wernher von Braun. He parlayed his practical experience with the VfR and his theoretical knowledge of physics into full-time work as a rocket designer for the German army. He rose quickly to project management and director, as a civilian. As Germany plunged into the dark days of war and the terrorizing years of war crimes, Wernher von Braun found himself a key player in developing what the Nazi dictator Adolf Hitler called the "secret weapon"—the V-2 rocket.

Von Braun maintained later that he was unaware of the concentration camps, the starving and gassing of prisoners, and the persecution of Jews and other groups, such as homosexuals and gypsies, that the Nazis pronounced inferior. He was single-minded with a job to do and his country at war. Certainly, most news available in Germany was propaganda. For von Braun, also, designing rockets continued to be a job that would ultimately lead to space travel. Hitler used the rockets to bomb his enemies, killing thousands of civilians in England and the Netherlands, but von Braun did not take responsibility for that use, nor for the treatment of the imprisoned workers who assembled the rockets. Should he have?

Later, after he and his rocket team of about 100 men and their families came to the United States, he pushed for his team to receive the chance to build rockets for space. Without question, Americans have von Braun to thank for the successes of their country's space program. The wisdom of his developmental policies, understanding the importance of redundancy (having a backup for safety), his dedication and his excellence as a leader were all necessary ingredients for the entire Apollo program and the success of its missions to the Moon.

Von Braun became a key spokesperson for the entire enterprise of exploring space. For this, one of his greatest successes was the alliance he built with entertainment maven Walt Disney, creator of Mickey Mouse. "What a scene," one of Disney's artists later recalled. "I'd give a million dollars to spend one more day of that," he added. "It was a happy time, every minute of it was happy." They worked at high torque, some two dozen people standing or sitting around long tables, intently working and talking over drawings, sketches, and storyboards.

Amid their clatter, chatter, and frenzied activity, the recorded strains of Andrés Segovia's classical guitar ebbed and flowed.

This was also a happy, creative time for von Braun. Tall, suntanned, and blond, his head could be seen bent over drawing boards or speaking to an artist working nearby. It was a strange, vivid contrast for the former builder of Germany's V-2 rockets, by this time the guiding light of the American space program and its rockets. To him, the bustle of the environment, the cooperative spirit in the air, and the intense focus of those around him were reminiscent of "the Team," as he always called his rocket teams.

The year was 1954, and by special arrangement—sandwiched in among his enormous rocket development responsibilities—von Braun was consulting at the Walt Disney Studios in Burbank, California, helping Disney's top artists, writers, and production people put together a television show on the visionary world of space travel.

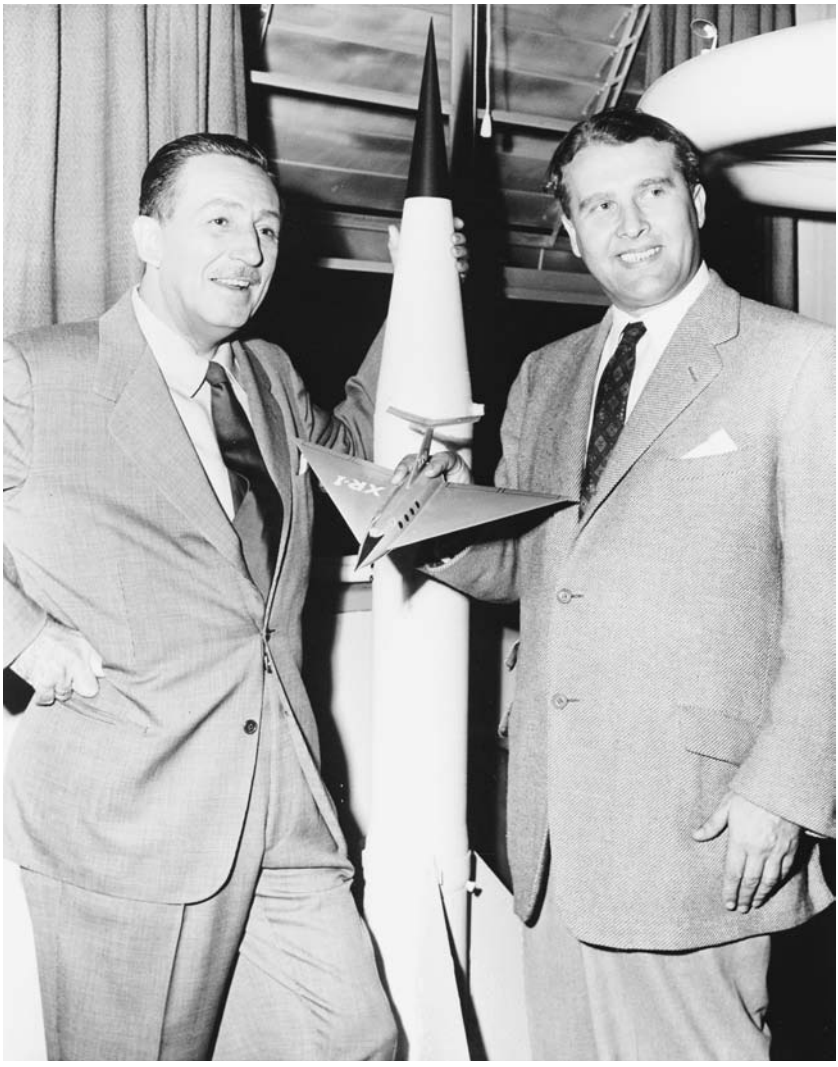
It all began, according to Disney writer Charles Shows, when he gave Disney a stack of *Collier's* magazines containing articles about life in the future. Disney was building Disneyland at the time and he and his team had no ideas for what to put in Tomorrowland, the area of the theme park that spurs the imagination to conjure up a sense of the future.

"This is the way to go," Shows remembers Disney saying. "We don't want any science fiction in Tomorrowland. These guys [covered in *Collier's,* including von Braun] seem to know what they are doing—let's get them out [to the West Coast] and let them be part of it." They got hold of Willy Ley first and he suggested von Braun.

According to Shows, "Walt was the kind of guy who wanted things perfect." Down to the last detail. "While von Braun was there, everybody was wrapped up in space. Von Braun worked on it just like he was building the rocket to go to the Moon."

It was that exciting. "The place just reeked of excitement. Everybody put their heart and soul into it. It was like a new hobby everybody suddenly had," Shows added. For Wernher von Braun, though, it was always more than that: It was another step toward fulfilling his dream—a dream of building rockets and flying to the planets that had obsessed him since childhood.

Now the dream had an added dimension. He had become a celebrity and national popularizer of humanity's step into the space age.



Rocket scientist Wernher von Braun (right) collaborated with entertainment maven Walt Disney to spark American enthusiasm about rocketry, spacecraft, and the adventures of exploring interplanetary space—the realms of Tomorrowland at Disney's theme park known as Disneyland. (NASA/NACA)

His teen years when he had helped design and construct his first small rockets from salvaged scrap in Berlin in the early 1930s seemed far off no doubt. So, too, he felt light-years away from Peenemünde, where under Hitler's orders he had provided the missiles that devastated the heart of London. The world had changed and he had

changed—and yet, in many ways, he had remained constant, always in love with space.

This revised edition of *Wernher von Braun,* part of the 10-volume Makers of Modern Science set, examines the complex issues brought to light by the availability of documents that were at one time labeled "Top Secret." A new chapter at the end of the book explores the significance of von Braun's statements to the U.S. Army concerning his wartime career as a V-2 rocket builder and a member of the National Socialist German Workers' Party (Nazi), as well as his commission in the SS (secret service). Recently, writers have become highly critical of these two affiliations, which were suppressed in official NASA histories of von Braun's work for the U.S. Army. This chapter emphasizes some of the ethical issues raised by von Braun's story. What is the truth about von Braun's work in Germany during the war? Did von Braun know about the 6 million Jews who were tragically annihilated by Germany's Nazi regime? Was he aware of conditions in Nazi concentration camps? Certainly he understood why the army wanted V-2 missiles. What are a scientist's responsibilities? Is a scientist, or anyone, responsible for what other people do with what they invent, design, create, and build? Did the United States make an error of judgment with "Operation Paperclip," the program that allowed them to invite von Braun and his team to come here? What would today's Homeland Security have thought?

This revised edition also contains new sidebars and expanded coverage of individuals such as Hermann Oberth and Willy Ley, the American Rocket Society, von Braun on civil rights, and many other relevant topics. This volume also includes a new chronology of key events in von Braun's life; recent publications on von Braun, rocketry, and the U.S. space program; and related URLs that can provide other topics of interest. These tools are intended to help readers resolve some of the mysteries and meet some of the challenges presented by von Braun's character—and to become aware of the dilemma raised by a pragmatic recognition that, had von Braun not come to the United States in 1945, the Union of Soviet Socialist Republics (USSR, now Russia and neighboring nations) would almost certainly have won the cold war.

1

Runaway Rockets, Stars, and Space

Born on March 23, 1912, in Wirsitz, in East Prussia (now Wyrzysk, Poland), Wernher Magnus Maximilian von Braun came from a family of aristocratic landowners. The second of three children, he had an older brother, Sigismund, and a younger brother, Magnus. Wernher's father, Magnus von Braun, was a baron whose family had resided in the sleepy region of Silesia for more than three centuries. His mother, the former Emmy von Quistorp, was a woman of great culture and learning. Her family, originally from Sweden, had lived for many centuries in Mecklenburg (now in northeastern Germany) and Pomerania (now in northern Poland).

Early Musical Talent

While Wernher was still a toddler, his parents noticed his remarkable memory and linguistic ability. Not only could he read the

newspaper at age four, but he could also read it upside down. He had the ability to lock onto a project and finish it quickly, and he was always asking questions that puzzled even his teachers. While his brothers were both bright, his father would sum up, Wernher was a genius.

Wernher's mother was from an aristocratic Swedish/German family that valued intellect, and she was quick to encourage her young prodigy. She brought an intellectual and cultural richness to her family—a solid amateur interest in ornithology (the study of birds) and astronomy, as well as fluency in six languages. She saw that he had a great love of music and, when he was a young child, liked to make up compositions on the piano. He was so talented in music that his mother later said she had thought he might make music his career, and he did write several short compositions, took piano lessons from well-known composer Paul Hindemith (1895–1963), and played the cello. His favorite subjects were language and music, and he disliked mathematics and physics. Yet he traded those early years of sound and rhythm for the abstract rigor of science and math because he had found a dream that would haunt him all of his life—the fascination and challenging demands of an idea he first encountered in his early teens—the dream of voyaging into the realms of interplanetary space. (Here, too, his mother's influence seemed to encourage his best talents, opening the doors of science and astronomy with the gift of a telescope.) Once he discovered this otherworldly preoccupation, he never let go of it. Grazing the fringes of space and soaring beyond Earth's atmosphere became his everlasting preoccupation and his life.

Neither Wernher von Braun's aristocratic heritage nor his rural background nor his remarkable musical talent would play much of a role in his life, except, perhaps, in giving him the towering confidence he would display in his later years. A more important influence was the Germany of his childhood.

1920s Berlin

World War I began two years after Wernher was born, and he was six by the time the war had come to an end, in 1918, with Germany's defeat. Economically devastated by the war and punished for its

aggressions against neighboring countries, the German nation was forced to accept responsibility for initiating the conflict. Its military was sharply curtailed and controlled, and the nation was required by the Treaty of Versailles to pay a staggering $5 billion in war debts. For the German people, with their long tradition of national pride and self-assurance, these humiliations were difficult to swallow. In the ensuing attempt to rebuild their country and its self-esteem, the German people set aside their long-held system of autocratic rule to try democracy for the first time—setting up a shaky constitutional government known as the Weimar Republic.

The new government found itself plagued with economic disaster and skyrocketing inflation. The von Brauns, though, were more fortunate than some, and while life was difficult, it was not unduly hard. By the early 1920s the family had moved to Berlin, where Wernher's father had become minister of agriculture and education in the new Weimar government's cabinet.

Vibrant and crowded, Berlin in the early 1920s suffered economic depression along with the rest of the nation, but the city also began to take advantage of some of the freedoms that came with Germany's new experimental democracy. Censorship was eased and long-held traditions were abandoned or questioned. The city became a thriving hub of artistic and cultural activity, of opera, theater, and filmmaking. Artists and writers flocked to Berlin, many coming in from cultures beyond the German borders, as in the case of British authors W. H. Auden and Christopher Isherwood. Musicians, dancers, and artistic hangers-on filled the city's streets. With the high arts also came the lower forms—countless bawdy revues, vaudeville acts, and nightclubs lit up the city's nightlife.

Like much of the rest of the world in the 1920s, Berlin also was exploring new ideas about the liberation of women and sex. Restraints were being cast aside; young women wore shorter skirts and danced wildly in public, while young men carried hip flasks filled with alcohol. The atmosphere was at once exhilarating and tense, a strange, dark carnival of freedom and resentment, humiliation and pride. Loud jazz music competed with militaristic jingoism, and free-thinking artists and freewheeling flappers and dandies shared the busy streets and the frantic nights. Yet many Germans remembered the old order and yearned for the days when Germany

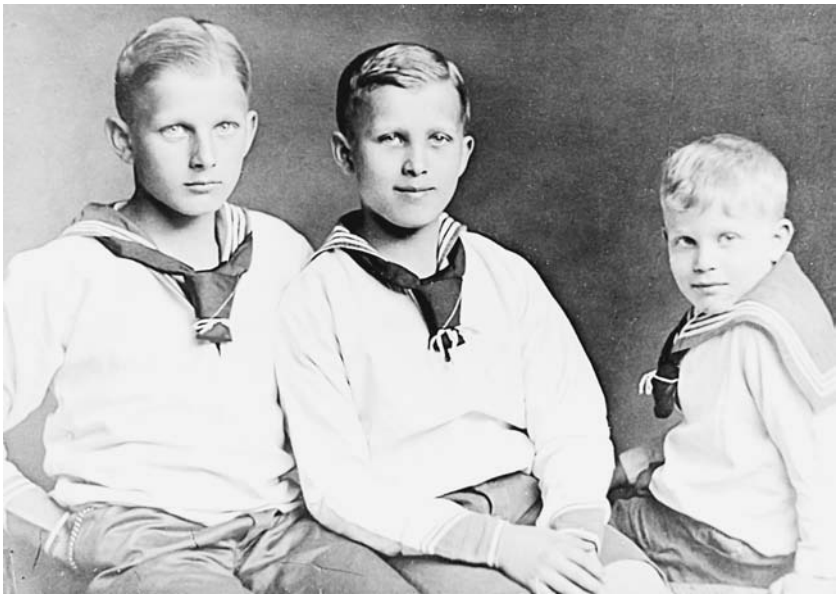
was strong and its citizens disciplined, when the nation was powerful, respected, pure—and immune from the decadent influences of the rest of the world.

As a boy, Wernher von Braun (whose name is pronounced VURNER FON BROWN in German and WURNUR VAHN BRAWN in English) showed little interest in the politics or social changes of his time. He shared this indifference with many other children of the aristocratic upper middle class who remained aloof and indifferent both to the working class and their day-to-day lives and to the bohemians and their liberated notions of political, sexual, and artistic freedom.

Wellspring of Science

Yet there was another face of Germany in the 1920s that did capture the interest of Wernher and many of his contemporaries. The growing prospects and products of science and technology had seized the imagination of the nation, and Germany—especially Berlin—was the place to be for anyone working in physics or chemistry. There exciting breakthroughs were taking place every few weeks, and Nobel prize-winning work was the rule of the day. Albert Einstein went to Berlin to work on his theory of relativity, and other great physicists and mathematicians, including Max Planck, Wolfgang Pauli, Erwin Schrödinger, and Werner Heisenberg, gathered to study or lecture in the great German universities.

Even those who were not ready for or interested in the challenge of science were caught indirectly in its web. Many young readers pored excitedly over the novels and stories of Jules Verne and H. G. Wells—tales about adventurers who plunged to impossible depths under the sea and voyaged through space to the craters of the Moon. Around them, it seemed, technology and the fruits of science were already well on the way to providing the means for such grand adventures. The airplane was still relatively novel and adventurous, and the automobile was still as freshly exciting as a child's new toy. And with the 1920s came a new fascination: the power of rocketry and the exciting, astounding possibility that rockets could provide the means for voyages into space, to the Moon, the planets, and beyond.



Wernher von Braun (center) was about 12 when this picture was taken with his two brothers, Sigismund (left) and Magnus, who both shared his fascination with rocketry. (NASA Marshall Space Flight Center)

As children, Wernher and his brother Sigismund tried their hands at shooting off small rockets purchased from the neighborhood fireworks stand. As Sigismund later told the story, one of them "landed in a fruit stand and ruined some perfectly good apples." The two boys were grounded after this early adventure and Sigismund abandoned his adventures in amateur rocketry, but Wernher was not discouraged so easily. Showing the kind of tenacity that would become his trademark for the rest of his life, soon he launched another—which promptly landed in a bakery. He also managed to cause a king-size commotion when he attached a couple of fireworks-style rockets to a small wagon and sent it careening wildly down busy Berlin streets.

"The wagon," von Braun later recalled, "was wholly out of control and trailing a comet's tail of fire, but my rockets were performing beyond my wildest dreams." The wagon finally came to a stop when the rockets burned themselves out. Some tempers also had been ignited, though, and this time young Wernher found himself in police custody. Only his father's timely intervention saved him from

a more severe reprimand, at least from official sources. Once again Wernher found himself grounded, and was strongly advised to spend more time with his schoolwork and less with his rockets.

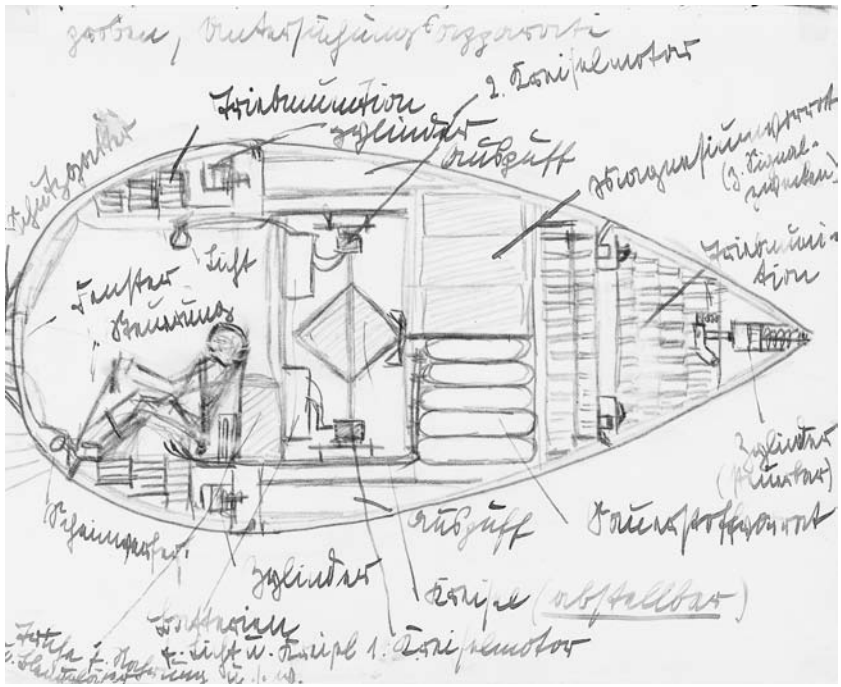
Schoolwork did not interest him much in those early years, though. The man who would one day explain physics and space science to the American public on Walt Disney's television program did all right in art and music, but he found most of his other classes dull and not worth the effort.

Things began to change when his mother presented him with a small telescope at the time of his confirmation (or full admission into membership in the Lutheran Church). It was an inspired idea, appealing to Wernher's profound imagination, and he soon began to spend his evenings sweeping the night sky with his telescope's small lenses.

At about the same time his father decided it was time for an educational change and sent Wernher to Ettersburg Castle, a boarding school near Weimar (southwest of Leipzig in central Germany). One of several schools in Germany known for their progressive teaching methods, Ettersburg had a unique curriculum for its time. Students spent six hours a day on traditional academic studies, but devoted the afternoons to building and farming projects that developed construction skills such as carpentry and bricklaying. The curriculum was much more to active Wernher's liking, and he still usually had an hour or two in the evening to use his telescope.

Besides reading science fiction, he also had begun to buy and read astronomy magazines. One night an advertisement caught his interest. The ad was for a book called *Die Rakete zu den Planetenräumen* (*The Rocket into Interplanetary Space*) and featured a picture of a rocket, hinting at its amazing possibilities. Wernher sent for the book immediately, and when it finally arrived weeks later, he turned the pages with tremendous excitement. Maybe it would tell him how to build a real rocket!

Excitement quickly turned to confusion and disappointment. The book was short—a slim 92 pages—and the first pages he looked at were filled with obscure mathematical formulas and physics equations! To him, it looked like total gibberish. Wernher flipped quickly to the second section. A diagram of a rocket. Good. But more physics



When Wernher was about 15 or 16, he drew this detailed sketch of a crewed spacecraft, with parts labeled carefully in German (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

and math—not so good. They were his worst subjects. How could he ever figure all this out?

But the third section was different. There the author—a theorist named Hermann Oberth (oh BAIRT)—outlined his ideas about how rockets could be used to escape Earth's gravitational pull and fly free through space to other planets in the solar system. The text described the spaceship as well as supply depots in space and the type of clothing space travelers might wear. It was like reading an outlandish fantasy, a Jules Verne or H. G. Wells science fiction tale. Yet this book filled with mathematics and physics said that space exploration might truly be possible, some time in the not-too-distant future!

It was tremendous stuff, but a little frightening. The rockets needed to accomplish such marvels had to be much larger devices, much more complex than the simple fireworks Wernher had played

with as a child. If he really hoped to build the kind of rockets that could take human passengers into space, Wernher realized that he would have to know mathematics and physics. He would also learn that his dream would require discipline and hard work. And, perhaps most important of all, he would discover what it was like to be possessed and driven by a single great idea.

To Wernher von Braun, his future path seemed inevitable. He would learn what he had to learn. He would do what he had to do. Although still in his teens, von Braun had taken his first steps into genius. He was obsessed with a single great idea, an idea from which he would never swerve, and one that would control, for good and bad, all the future decisions of his life. From then on there would be no other direction for him. He would do whatever was necessary to fulfill his dream of building rockets. And someday those rockets would take human beings into space.

His dream would provoke loathing and controversy, admiration and glory. He would live it until his final days.

He was not, however, the first to have such a dream.

2

Beyond Earth's Atmosphere

When Wernher von Braun first read Oberth's little book on rocket power, rockets had already been around for a long time. Their first recorded use occurred in China, where warring factions in the 13th century used "fire arrows." Not only could these arrows with simple rockets attached fly farther than ordinary arrows, but they also carried an incendiary substance that caused fires where they landed.

Within a few years, military use of rocket-powered weapons had spread throughout Asia, to Africa and Europe. In Europe and England, interest in rockets as weapons tapered off after about the 15th century. But in Asia, as late as the last half of the 1700s, any military operation always included at least one or two corps of rocket throwers.

Rocket Weapons in Eighteenth-Century Warfare

When the rocket throwers in the army of Haidar Ali (1722–82) won battles against British troops in India in the mid-1700s, the British military suddenly gained a renewed respect for these frightening, flaring projectiles used in long-range barrages. The Indian soldiers' rockets were made of thick bamboo, about 8 to 10 feet (2.4 to 3.1 m) long, attached to a tube of iron, which contained the fuse and powder. The range of these rockets may have been as great as 1.5 miles (2.4 km), and, while their accuracy was limited, psychologically their effect was devastating.

This image portrays a rocket corps soldier in the army of Tipoo Sultan in India c. 1793–94. In the late 18th century, Tipoo Sultan's army owed several triumphs against Britain to the strength and achievement of the Mysore army's rocket technology in southern India. (© Private Collection/The Stapleton Collection/ The Bridgeman Art Library)

Around 1770, the British got hold of a few of these weapons. No one in the British army succeeded in reproducing their range, or even their less-than-perfect accuracy, until 1804, when William Congreve, a British ordnance officer, came up with some ideas for improving range and accuracy. Congreve also recognized an important fact: A rocket has no recoil (the push backward that occurs, for example, when a shotgun is fired). For this reason, he realized, rockets could be launched from sea, without fear of capsizing his navy's boats.

On October 8, 1806, 18 rocket boats loaded with men and officers in the Royal Marine Artillery used Congreve's improved rockets to excellent advantage against

How Do Rockets Work?

Rockets work on a jet-propulsion principle. When an inflated balloon is untied, jet propulsion is the force that sends it careening across the room. The air inside a sealed balloon presses against all sides equally at once. But when the neck is untied, the air pressing against the neck suddenly escapes through the hole, creating a pressure imbalance. Now the air at the top of the balloon is pressing more forcibly than the air at the neck, which is meeting almost no resistance, and the balloon is pushed in the direction of the increased pressure. (The balloon is not propelled by the air rushing out the neck, as many people think.)

People have known about jet propulsion for a long time—for example, in the second century C.E., Hero of Alexandria demonstrated the power of escaping steam to move a machine he devised, and in the 17th century Isaac Newton established the principle behind this power with his third law of motion: For every action there is an equal and opposite reaction.

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The Forces at Work in a Rocket

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This diagram illustrates the forces at work within a rocket—with forward-moving gaseous pressure that is unbalanced, creating the propulsion that causes the rocket to fly.

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In a rocket, burning fuels produce gases, and heat causes the gases to expand. The gases escape through an opening at one end of the rocket (the nozzle). As gas escapes from the rear, gases within the rocket press forward, propelling the whole device forward. This is what gives a rocket its traveling power.

What made rockets especially interesting to space enthusiasts like von Braun in the early 20th century was one major fact: Rocket engines don't need air to operate. Rocket engines contain within them everything they need to work—both fuel and an oxidizer (a substance that can produce the oxygen required by the fuel to ignite and burn). This means rockets can work as well in space as in the Earth's atmosphere because the oxidizer is carried either as part of the fuel or in a separate compartment.

Jet engines, by contrast, are "air-breathing" engines. Unlike rockets, they take oxygen from the air, combine it with the fuel they carry, ignite the combined mixture, and propel themselves forward from the energy produced. These engines could never be used beyond Earth's atmosphere.

Napoleon's French invasion fleet, moored at the harbor at Boulogne, France. The following year British attacks using thousands of Congreve rockets virtually destroyed a large French fleet at anchor in the harbor of Copenhagen and, with it, much of the Danish capital city. The British also used Congreve rockets to pelt Fort McHenry from Baltimore Harbor during the War of 1812 against the United States—creating the "rockets' red glare" mentioned in the U.S. national anthem, "The Star-Spangled Banner."

Despite the 19th-century British military successes, by the 1920s rockets had taken a back seat to other weapons—the big guns used by the Germans in World War I as well as tanks and howitzers (cannon that can shoot shells both very high and very far). The big 16.5-inch (420-mm) howitzer known as the Paris Gun could volley a 1,764-pound (800-kg) shell as far as 6 miles (9.6 km). With it the German artillery forces terrorized Paris during World War I. Rockets, as they had evolved by that time, seemed mild by comparison, and their

military importance faded again. For those interested in interplanetary travel, however, rockets—which can function in the vacuum of space—offered exciting possibilities.

In the early 20th century, nonmilitary uses for rockets soon began to gain ground—at least in the minds of a few individuals of mathematical talent and far-ranging vision. These theorists and engineers began to say that rockets could take us beyond the cradling atmosphere of Earth, into the cosmos. Rockets might have the power to escape Earth's gravitational pull. Rockets, in fact, might take us to the Moon.

Rockets That Reach Out to Space

At the time, this was an absurd-sounding proposition. But as the Russian theoretician Konstantin Eduardovitch Tsiolkovsky [tseel KOF skee] wrote in a letter in 1911, "Mankind will not remain on the earth forever, but in the pursuit of light and space will at first timidly penetrate beyond the limits of the atmosphere, and then will conquer all the space around the Sun." Both a sound theorist and a great visionary, this self-taught Russian schoolteacher was the first to put forth the idea of rocket-powered space travel, supported by equations and detailed physical descriptions.

In his paper "Exploration of Space by Rocket Devices," written in 1889 and published in 1903, Tsiolkovsky outlined his ideas for the use of rockets in space, including a diagram of a rocket spaceship. This work became one of the most significant papers in the history of rockets and space travel.

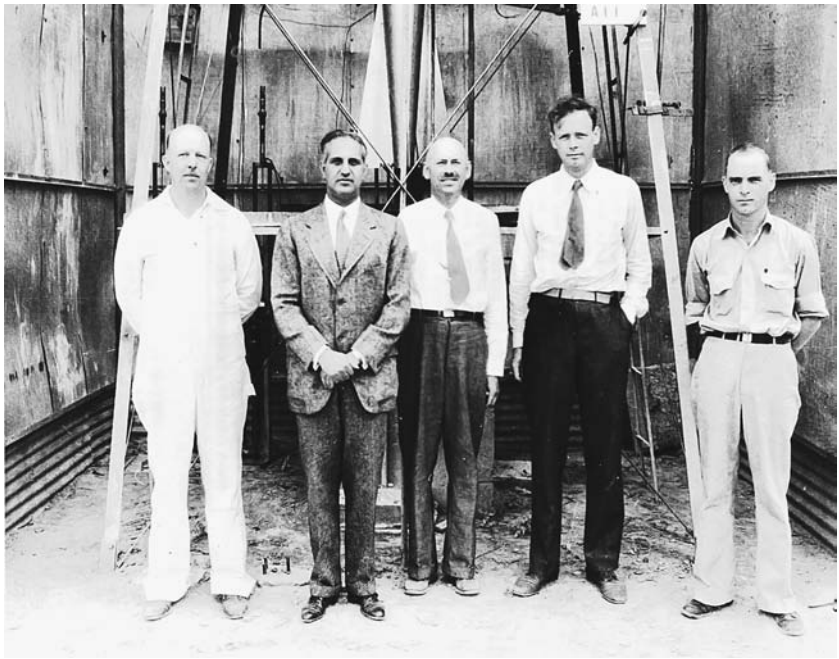
Tsiolkovsky never actually built a rocket, but as early as 1897 he had derived his now-famous formula (still considered valid) that establishes a ratio among a rocket's speed at any point in time, the speed of the gases expelled from its engine nozzle, the mass of the rocket, and the mass of the explosives consumed. He recognized that the rate of motion in empty space is theoretically unlimited (at least, as we now know, up to the speed of light). He also saw that speed depends solely on the exhaust velocity of gas particles and the ratio of the mass of explosives (propellants) to the mass of the rocket. This idea pointed toward the possibility of attaining the enormous speeds necessary to escape Earth's atmosphere.

Robert Goddard: Pioneer Rocketeer

In the United States, meanwhile, a lone, serious-minded engineer named Robert Goddard began filing for rocket patents as early as 1914 and was testing solid-fuel rockets regularly by the 1920s. In fact, in a paper he submitted to the Smithsonian Institution in 1919—entitled blandly "A Method for Reaching Extreme Altitudes"—he suggested that it would be possible to send a rocket to the Moon!

Many people immediately jumped to the conclusion that Goddard was a fool, a crackpot with ludicrous dreams. Goddard was dismayed by the hyped-up portrayal of his work, confiding later, when asked about his Moon rocket, "All I'm trying to do is get this thing off the ground."

On March 16, 1926, Robert Goddard made an enormous breakthrough when he launched the world's first successful liquid-fuel



This photo shows American rocket engineer Robert Goddard (center) on September 23, 1935, with Charles Lindbergh (right, next to Goddard), who believed in Goddard's work and obtained funding for him from the Guggenheim Foundation. (Harry D. Guggenheim is next to Goddard on the left.) The group is standing in front of one of Goddard's rockets in its launch tower. (NASA)

rocket. It was an important landmark for the future of space travel, since only the liquid-fuel rocket was powerful enough to carry heavy cargoes upward beyond the edges of Earth's atmosphere. In technical terms, liquid fuels produce more pounds of thrust per pound of propellant burned per second, which means that liquid fuel adds less weight to a rocket while producing more power than solid fuels.

Goddard's work, like Tsiolkovsky's, was not widely known in Europe. Yet a German-speaking schoolteacher born in Transylvania (now in Romania) also had become intrigued with both the theory behind rocket propulsion and the possibilities for space travel offered by rockets and had been in communication with Goddard.

Hermann Oberth

In 1923 Hermann Oberth published the book Wernher von Braun sent for, *Die Rakete zu den Planetenräumen* (*The Rocket into Interplanetary Space*). In it he set forth the theoretical basis for large liquid-propellant rockets, including the multistage rocket—and he compared Goddard's conclusions with his own. In later years Goddard felt that Oberth received credit for some insights that were contained in his Smithsonian paper—and without question, many conclusions were similar.

In any case, the book was an immediate popular success, directly or indirectly inspiring many whose names would soon become famous in the history of rocket development—including Rudolf Nebel, who would build some of the earliest European rockets, and Willy Ley, who would become a well-known science writer and popularizer.

3

"Help Create the Spaceship!"

By the winter of 1929–30, amateur rocket builder Willy Ley had become one of the major figures of the movement to build rockets in Germany, and people interested in rocketry had begun to seek him out. Still, he was surprised when he returned home in Berlin one afternoon that winter to discover a visitor waiting for him. Ley looked back on that day in his book, *Satellites, Rockets, and Outer Space,* published in 1958: "I entered my home in Berlin and heard someone playing the piano. Since I knew that the only other family member who played the piano was absent, it had to be a visitor. It was, and I even remember what he was playing—it was the first movement of Beethoven's *Moonlight Sonata.*"

Early rocket enthusiast and journalist Willy Ley formed an important link in communications between the VfR and the German media. (National Air and Space Museum, Smithsonian Institution, [SI 2006 26076])

Cutting-Edge Amateur Rocketry

The young man sitting at the piano was Wernher von Braun, the young student who had once shown a greater talent for languages and music than for physics and mathematics. It seems he had already developed his lifelong knack for making himself at home, wherever he went. At the time, he was about 18 years old, studying at the Charlottenburg Technische Hochschule, a renowned technical school in Berlin.

"Physically," Ley would later note in a letter to the British Interplanetary Society, "[Von Braun] . . . had bright blue eyes and light blond hair and one of my female relatives compared him to the famous photograph of Lord Alfred Douglas of Oscar Wilde fame. His manners were as perfect as rigid upbringing could make them. . . ."

The reason for the memorable young man's visit became apparent quickly. He wished to join Ley and the small group of enthusiasts who had formed the amateur rocket-building society known as the VfR (*Verein für Raumschiffahrt,* or Society for Space Travel), by this time a well-established society with clearly defined goals. Ley was prominently involved, and von Braun hoped Ley would gain him access to the group.

Founded on July 5, 1927, in the back room of a restaurant called the Golden Scepter in Breslau (now Wroclaw, Poland), the group had a formal charter and serious objectives from the beginning. The charter set forth two principal purposes: (1) to popularize the idea of

Willy Ley (1906–1969): The VfR Voice

About six years older than Wernher von Braun, Willy Ley studied physics, astronomy, paleontology, and zoology at the University of Berlin and the University of Konigsberg. He soon discovered his lifetime passion—rocketry, rocket propulsion, and space travel. Meeting Rudolf Nebel and other rocket enthusiasts in Berlin, he helped found the VfR. A science popularizer and journalist, he became the voice of the VfR.

Born in Berlin on October 2, 1906, Ley wrote and published his first book on space travel in 1926, shortly after the publication of Oberth's book on the same subject. Called *Die Fahrt in den Weltraum (Travel in Outer Space),* Ley's book stirred up the beginnings of a following, and Ley and rocket theorist Hermann Oberth were offered positions as consultants for Fritz Lang's forthcoming film *Frau im Mond* (*Woman in the Moon*).

Ley continued to write books and articles about rockets and space travel until censorship began to take hold in Germany. Nazi authorities had begun to see rockets as potential weapons and they did not want Ley tipping secrets about the technology and mechanisms that made it work. By 1935, Ley saw that he would not soon regain the freedoms he had had before, and he was too outspoken to just watch his step. The Nazis seemed to be watching everyone who had experience in this field, including every member of the VfR. After a brief stay in Britain, Willy Ley set out for the United States in 1935, and he became a U.S. citizen in 1944.

Living in the United States had its odd disadvantages—prior to the U.S. entry into World War II, Americans weren't interested in rocketry. However, Lei was a prolific writer and made a living from writing books and articles about the natural world, profiling salamanders and lungfish, serving as science editor for a New York newspaper, publishing in magazines such as *Popular Mechanics* and *Cowles Encyclopedia,* and lecturing in college classrooms. After the United States entered the war, interest became keen for information about the V-2s being dropped on London. Ley's passion for the subject was matched only by his readers'. His book *Rockets, Missiles, and Space Travel* went through several editions, and that was just the beginning. When von Braun arrived in the United States, he and Ley shared a byline on *The Conquest of the Moon* along with astronomer Fred Whipple. Ley's book *Conquest of Space* was illustrated by space artist Chesley Bonestell, who was featured in the *Collier's* (1952–54) series of articles on space travel, along

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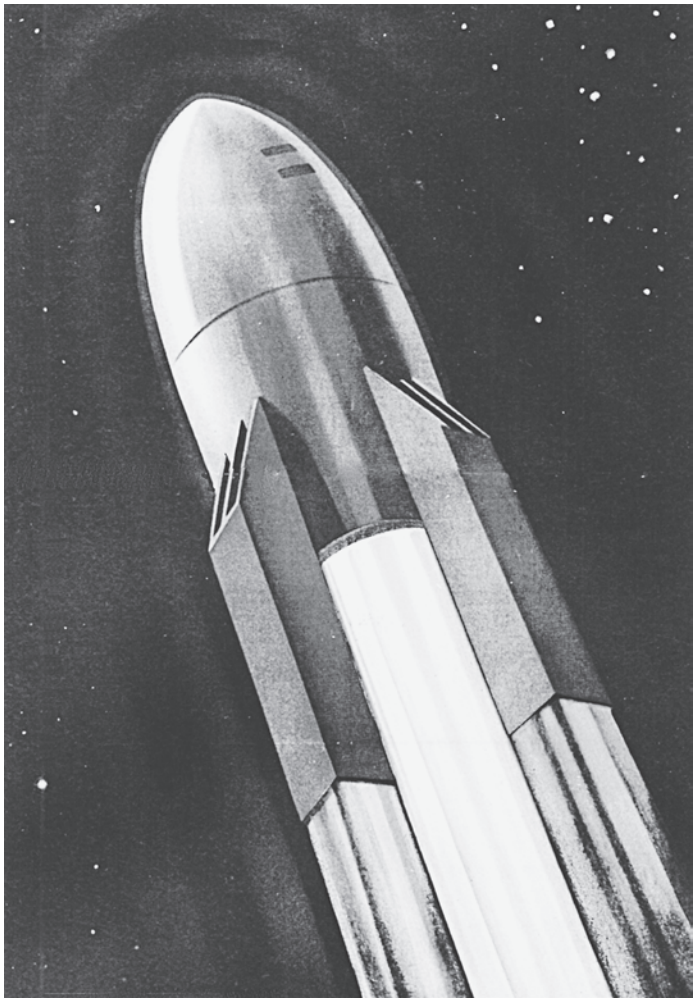
with Ley and von Braun. Ley, of course, was at the top of his form. Unfortunately, he died of a heart attack just four weeks before the liftoff of *Apollo 11* to the Moon. Willy Ley's invitation to the launch went unused.



This poster was part of the advertising campaign for director Fritz Lang's movie Frau im Mond (Woman in the Moon). (Photofest)

rocket flight to the moon and planets, and (2) to conduct serious experiments in the development of rocket propulsion.

It was an ambitious agenda, and the VfR was tireless in its diverse but dedicated activities—publishing posters, giving lectures, and holding public demonstrations, all of which met with enormous success initially.

Germany, with its national ego still battered by the World War I defeat, was badly in need of some reassurance, some new confidence in its citizens' abilities. The German people fell in love with the kind of engineering perfection required by the new technologies, and they found the idea of rockets romantically adventurous. Perhaps powerful, spacebound rockets could be built. And with them, perhaps, humankind could truly conquer the stars!

Space Travel at the Movies

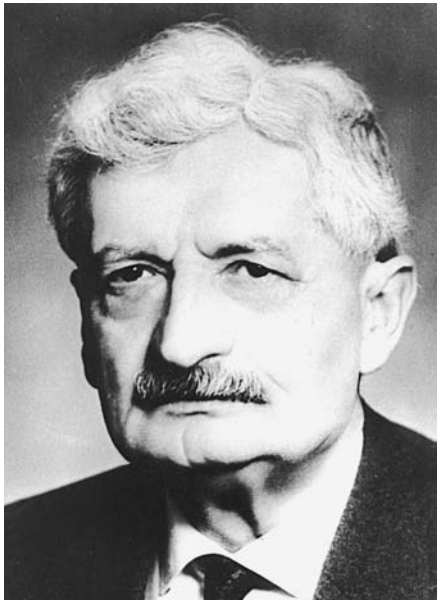
By the late 1920s, rockets had become such a hot topic that Fritz Lang, an internationally acclaimed German film director, decided to make a science fiction film, called *Frau im Mond (Woman in the Moon),* about traveling to the Moon. As Walt Disney would do 30 years later with his Tomorrowland programs, Lang wanted his film to be technically correct and immediately began looking for an expert on rocketry to hire as a technical consultant.

Lang also wanted a dramatic demonstration of the possibilities of rocket travel. He hit upon the idea of building a working rocket to use in a publicity stunt, planning to shoot it 70 feet (20 m) into the air above the Baltic Sea, and he turned to the man who had written the best book in German on the subject, Hermann Oberth. Eagerly Oberth agreed both to consulting on the film and to building the rocket.

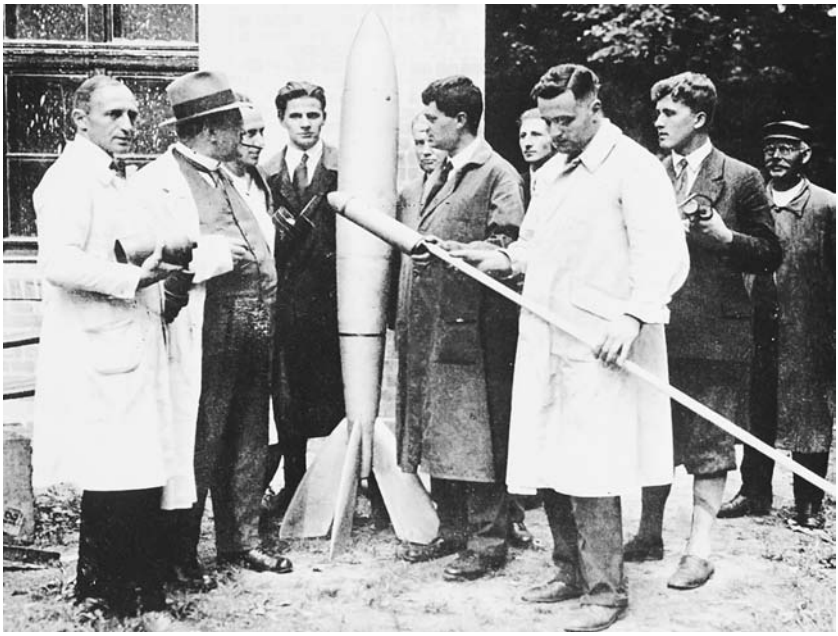
Unfortunately, the plan was overly ambitious. No one in Europe had ever shot a rocket that high (although American Robert Goddard, unknown to most Europeans, had sent his liquid-fuel rocket as high as 41 feet (12.4 m) by 1926 and 204.5 feet (62.31 m) by the end of 1928). Also, Lang didn't figure on the extreme difficulty of finding or manufacturing parts for rockets in 1920s Germany. And he had not, perhaps, chosen the ideal people for the job. Rudolf Nebel, who had been hired to assist Oberth, had piloted

a plane during World War I and had a degree in engineering, but had never actually practiced engineering professionally. Oberth was a sound theoretician but not strong in mechanics or engineering, and the parts he designed were probably unnecessarily complicated. As a colleague once put it, "If Oberth wants to drill a hole, first he invents the drill press." The manufacturers lagged abominably behind schedule, and although Oberth and Nebel labored frantically, the publicity deadline came and went and no rocket pierced the air over the Baltic Sea. Dejected, Oberth returned home to Romania for several months.

Meanwhile, Lang's film premiered without Oberth's rocket on October 15, 1929, and was a stunning success. The movie's advertising invited filmgoers to travel on the first spaceship to the Moon and experience the agony and the ecstasy of liftoff, the thrill of weightlessness, and the excitement of the first steps on the lunar surface. The film itself promoted the drama of rocketry, with searchlights playing dramatically on the Moonship as it awaited night launch. And Lang, recognizing a need to build suspense as the moment of launch approached, first came up with the idea of counting backward toward launch time: the first countdown. *Frau im Mond (Woman in the Moon)* boosted interest in rockets and the potential of space travel more than ever. And by the end of that year, the VfR had 870 members, swelling to 1,000 the following year.



Hermann Oberth was an early rocket theorist whose 1923 book, Die Rakete zu den Planetenräumen (The Rocket into Interplanetary Space)*, caught Wernher von Braun's interest early. It was the beginning of a life-long fascination with rocket transportation beyond Earth's atmosphere.* (NASA)



This group shot shows members and supporters of the VfR, including, among others: Rudolf Nebel (far left), Hermann Oberth to the right of the standing rocket, Klaus Riedel (in white coat holding a Mirak I rocket), and Wernher von Braun on the right in front of an unidentified onlooker. (Library of Congress)

Not long afterward, Oberth, his enthusiasm renewed, returned to Berlin and von Braun had a chance to meet him through his new VfR acquaintance, Willy Ley. The young man's enthusiasm struck a note with Oberth, who was working on a department store exhibit on rocketry. Would Wernher like to help? Of course!

Von Braun spent every spare moment helping Oberth set up the exhibit. When it opened, he was on hand and stepped in with an air of authority and assurance, answering questions with the confidence of an expert. Travel to the Moon, clearly, was not far off, he declared roundly to all who would gather about and listen. The technology was almost there.

The *Frau im Mond* rocket-building fiasco had produced a silver lining for the VfR and their dreams of developing working rockets. Oberth and Nebel came away with valuable experience in the realities of rocket building, and they also amassed a considerable

amount of equipment, including an essential iron launching stand. Willy Ley secured the equipment for the VfR (what would Lang want with it anyway?), and Oberth and Nebel continued their work, now under the auspices of the rocket society.

The VfR Keeps Advancing

The VfR's next break came when Nebel, Ley, von Braun, and several other members succeeded in obtaining permission to use an abandoned military ammunition dump in a suburb called Reinickendorf, south of Berlin. At last the group would have a place to test their rockets. They named their new test site *Raketenflugplatz* (rocket airfield) and moved in on September 27, 1930. There, in Reinickendorf, this group of ardent amateurs erected a sign reading "Raketenflugplatz Berlin" and set to work clearing the 300-acre (121.4 ha) grounds and converting the various buildings into storage areas and offices.

Wernher von Braun (right) was 19 or 20 in this photo c. 1932 of von Braun and Rudolf Nebel carrying two rockets at Raketenflugplatz, the VfR rocket testing grounds. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

That first year the VfR completed 87 launchings at Raketenflugplatz, testing various rocket motors designed by its members. The group also fired an impressive 270 static firings (in which the rocket motor is fired on a test stand without allowing the rocket to take off).

While VfR members readied Raketenflugplatz, von Braun sandwiched in more technical schooling, having set off during the spring of 1931 for the Eidgenossische Technische Hochschule (Institute of Technology) in Zurich to continue his engineering studies. In this quaint Swiss city, nestled among the mountains at the foot of Lake Zurich, far from home and the VfR, von Braun continued to talk space exploration incessantly.

By March 1931 he had struck up a friendship with an American medical student from the University of Zurich, Constantine Generales. During conversation one day over lunch with his new friend, von Braun embarked with ebullient enthusiasm on a discussion about future space travel and "getting to the moon."

Something about von Braun's earnestness must have saved the growing friendship from drying up that day, for "to me," Generales would later write, "this whole thing seemed very ridiculous." What turned the tide for the skeptical medical student was a letter von Braun showed him a few days later. The letter, according to Generales's account, was addressed to von Braun and signed by Albert Einstein, postmarked Berlin (although Einstein did not later recall this correspondence). As Generales recounted, "I stared at the indecipherable equations pertaining to mathematical problems and solutions in rocket design and propulsion. I was dumbfounded." If Einstein took this space travel idea seriously, Generales began to think, maybe it wasn't such a crackpot idea after all. And, while he wasn't knowledgeable about rocket engines, he did know physiology, and he began to apply his own knowledge to the issues of traveling into space.

Experiments: Can Humans Survive Space Travel?

What about human beings as space travelers? he wondered. Could the human body withstand the forces it would take to escape Earth's

gravity? What would happen to muscles, organs, and bodily functions under the pressure of several gs (a g is the normal force of Earth's gravity), which would stress the body as it sped toward outer space? The answers to these questions had to be established before humans could venture into space.

"Wenn Du zum Mond gehen willst ist es viel besser zuerst mit Mausen zu versuchen!" he told von Braun pragmatically. ("If you want to get to the Moon, it is better to try with mice first!") And so began what probably were the world's first experiments in space medicine.

In July through August 1931, Generales and von Braun had built a primitive centrifuge—a bicycle wheel, bolted horizontally to a table and rigged with a belt so it could be turned with a hand crank. To its perimeter, the two students attached containers to hold the white mice they used as test subjects. With the spinning bicycle wheel they could simulate, approximately, the accelerative force that anyone aboard a spacebound rocket would experience as it launched.

"We had no idea what the tolerance of the mice would be," Generales would later recount. "In the beginning, after a few turns of the wheel, the poor mice, whose hearts you could feel pounding in the palm of your hand, were placed on the table. We observed how the little creatures would scramble slowly at first and then faster in spiraling fashion . . ."

In addition to this type of observation, Generales also dissected the mice to document what happened inside physiologically. After subjecting the mice to higher accelerations, he observed such indications of extreme stress as internal bleeding, especially in the brain, and displacement of the heart, lungs, and other organs. Using these reactions in mice as an indication of what might happen to humans, he realized that some measures would have to be taken to protect future space travelers from this much acceleration.

The two students certainly considered their efforts to be scientific research, and the unsentimental pragmatism with which they proceeded was typical of von Braun throughout his life: What do we need to know? How can we find out? Von Braun's Swiss landlady, however, did not appreciate the spatters of mouse blood on

her walls and threatened him with eviction if the experiments did not stop.

So von Braun and Generales dismantled their apparatus and closed up shop. Von Braun shortly returned to Berlin and the VfR at Raketenflugplatz, where opportunity was about to knock in a very big way.

4

Rocket Engineer for the German Army

The excitement at Raketenflugplatz was intense one spring morning in 1932 as members of the VfR made last-minute preparations. If things went right, their financial problems might soon be over. They had caught the attention of the Reichswehr, the army of the Weimar Republic—and a contingent from the Ordnance department of the army was on its way to their test site to see what sorts of rockets the enthusiastic group had been working on.

Always eager to show off their rocket hardware, the members of the VfR had high expectations, as the motor car pulled at last into the grounds in Reinickendorf. One by one an austere group of solemn-faced men stepped out, dressed not in uniform, but in drab civilian clothes.

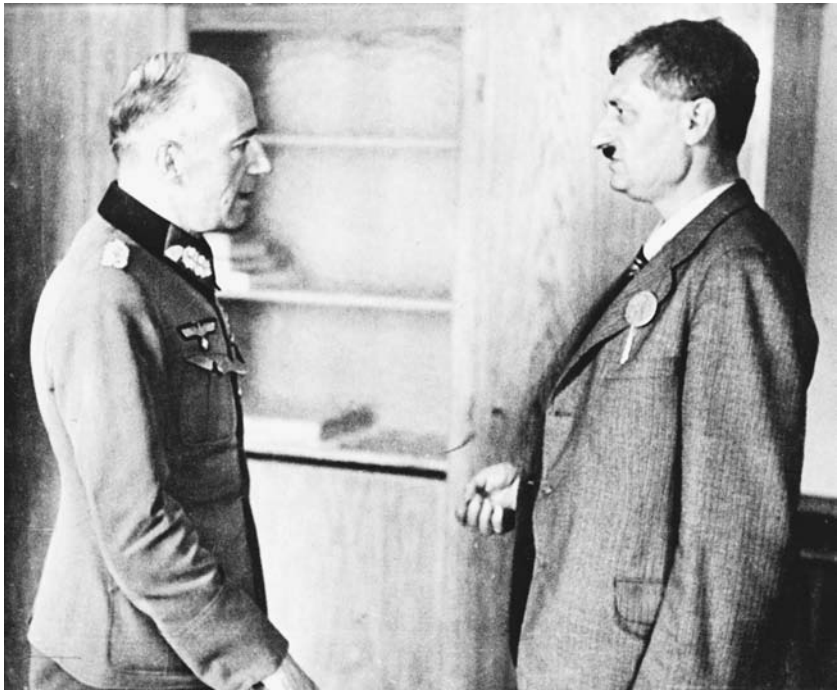
With energy and excitement, the VfR's welcoming committee set about giving them the grand tour. The crisp spring air echoed

with the crunch of leather shoes on gravel, in contrast to the stony silence of the army visitors. The sharpest-eyed of the strangers, Captain Walter Dornberger, took special note of every detail.

Dornberger's Agenda

Dornberger had a particular interest in the VfR's activities. Conditions in the Treaty of Versailles had forbidden Germany from developing heavy weapons or the armed forces to use them. But, through some oversight—or simply a lack of foresight—the treaty had not mentioned rockets. And in 1929, looking for ways to sidestep this crippling agreement, the German army had assigned the balding, 35-year-old Dornberger to develop a liquid-fuel rocket for possible military use.

Dornberger, who held a masters of science degree in engineering at that time, had established an experimental station at the



Walter R. Dornberger was von Braun's boss at the rocket testing grounds at Kummersdorf, a forested location about 30 miles (48.3 m) south of Berlin. Dornberger (at left) is pictured here a few years later, in about 1942, with early rocket theorist Hermann Oberth. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

Kummersdorf army ammunition proving grounds 18 miles south of Berlin and had begun his own experiments with solid propellants. In the process, he learned firsthand some of the difficulties and dangers of rocket building. Ignoring his own safety rules, he once attempted to disassemble a solid-propellant rocket by using a steel hammer and chisel instead of safer copper tools. The sparks from the steel tools set off the rocket propellant, driving thousands of tiny black-powder particles into his uncovered face. Removing the particles had taken a year of painful visits to the military hospital, where each particle was worked out by rubbing Dornberger's face with butter and then withdrawing the particles one by one with a pair of tweezers. For members of the VfR, that morning in 1932 was just about as tense and painful.

Spotty Results, Stellar Know-how

As Dornberger would later relate in his book *V-2* and in interviews, it was obvious that the amateurs had done some impressive experimental work with rockets—but the group had no discipline, no accepted scientific procedures. They had kept no detailed records of their tests, had plotted no curves showing the degrees and range of thrust they had achieved. They had not plotted a single rocket motor's performance on a graph. In short, while the hopeful young rocket men were enthusiastic and talented enough, they also were undisciplined, unscientific, and, certainly, unmilitary in their approach.

The army was less than pleased.

As von Braun would recall in an interview shortly before his death in 1977, the army officers who visited did not like "what they called our 'circus-type' approach. We would invite people for an entrance fee to witness our launches. . . . 'What we really want,' von Braun recalled their saying, 'is data, meaningful scientific material.'"

But despite their hit-or-miss approach and their obvious lack of accepted procedure, the VfR was building liquid-fuel rockets. So, based on the low-profile, though tension-filled, official visit to Raketenflugplatz, the army awarded a 1,000-mark contract to the VfR to build a "single-stick" rocket, which the VfR called Mirak II.

The VfR contended with two major problems in their rocket development—overheating and lack of stability. By 1931, they had

added aluminum walls cooled by water to the combustion chamber, which greatly cut down on explosions caused by overheating during combustion. With Mirak II, the group hoped that adding a single stabilizing stick to the tail would provide the even vertical flight they needed. It was a simple modification, and Mirak II was soon ready for demonstration. Von Braun later described its launch, in July 1932, at the army's proving ground at Kummersdorf:

> *Early one beautiful July morning in 1932 we loaded our two available cars and set out for Kummersdorf. . . . As the clock struck five, our leading car with a launching rack containing the silver-painted Mirak II atop and followed by its companion vehicle, bearing liquid oxygen, gasoline, and tools, encountered Captain Dornberger at the rendezvous in the forests south of Berlin. Dornberger guided us to an isolated spot on the artillery range where were set up a formidable array of phototheodolites, ballistic cameras, and chronographs—instruments of whose very existence we had theretofore been unaware.*

By 2:00 P.M. the rocket was fueled up and ready to go. The moment of liftoff came, and the signal was given. The rocket gave a belch and soared, reaching a height of 200 feet (60.9 m) or more. But suddenly it became apparent something was wrong. The rocket leveled out, following a nearly horizontal path, and finally crashed before the parachute could open.

Overall, the army was not charmed by the VfR. These men knew more about liquid-fuel rocketry than just about anyone else in Germany, but clearly they couldn't build a rocket you could depend on.

Still, Dornberger did not come away empty-handed. If he could not contract successfully with the VfR to build a viable rocket, he still might make use of the expertise of their best members. His attention settled on one who stood out from all the rest. As Dornberger later wrote in *V-2:*

> *I had been struck during my casual visits to Reinickendorf by the energy and shrewdness with which this tall, fair young student with the broad massive chin went to work, and by his*

astonishing theoretical knowledge. . . . When General [then Colonel] Becker later decided to approve our army establishment for liquid-propellant rockets, I put Wernher von Braun first on my list of proposed technical assistants.

Opportunity Knocks

It was the beginning of what would become a long and challenging adventure for Wernher von Braun, one that would take him into the disastrous infamy of war and the triumphant glory of space.

Von Braun was called in by Colonel Karl Becker, Dornberger's boss, to meet with him at the Army Weapons Office, and they struck up an immediate rapport. Becker offered von Braun a civilian position developing rockets for the army, and he further insisted that von Braun pursue a Ph.D. in physics at the University of Berlin, working under Erich Schumann, who also headed the research section of the army's Ordnance Department. Von Braun could use the experimental resources at Kummersdorf to complete his thesis work, which would deal with liquid-fuel rocket engines.

To von Braun it was an unbelievable break. He hurried back to the VfR with the news—the army was interested in research done under its sponsorship and direction, on its grounds. Nebel scoffed. He had no interest in succumbing to military priorities, and other key VfR members shared his aversion. But by now von Braun had concluded that rocketry had gone just about as far as it could in the hands of amateurs with limited funding. Real progress—the kind needed for reaching space—would require more discipline and much more money. So on October 1, 1932, Wernher von Braun became a civilian employee of the German army. On that day, for him, rocketry ceased to be a purely amateur enterprise and became a professional mandate for developing a military weapon.

In an article von Braun wrote 24 years later, he asserted, "It is, perhaps, apropos to mention that at that time none of us thought of the havoc which rockets would eventually wreak as weapons of war. . . . To us Hitler was still only a pompous fool with a Charlie Chaplin moustache."

Nebel, meanwhile, turned out to be wrong that the VfR could hold out, continuing its work on its own terms. By the spring of

1933 forces beyond the VfR's control began to close in on them. The Luftwaffe turned up one day to announce that the air force would be using Raketenflugplatz as a drill ground. Then the group received a utility bill for 1,600 marks—apparently because various water pipes on the property had been leaking for years and accruing charges. The VfR could not pay and the group was turned out. In any case, by 1933 the Nazis disbanded all rocket development not sponsored by the government. The VfR's exciting contribution to rocketry had come to an end.

At the age of 21, Wernher von Braun moved into the army installation at Kummersdorf West, where Dornberger supplied him with a single rocket test stand and three colleagues, Walter Riedel, an engineer from the Association for the Utilization of Industrial Gases; Arthur Rudolph, an engineer; and Heinrich Grünow, a master mechanic from the VfR's Raketenflugplatz.

Immediately the four of them set to work on a shoestring budget. Because rocket development by the army was a violation of the Versailles Treaty in spirit, if not in actual fact, the entire operation had to be carried out in secret, and nothing about the acquisitions for the group could look suspicious, even to auditors within the army. So Dornberger was forbidden to order any office equipment or machining tools. As he later would relate:

> *We acquired things "as per sample." For instance, even the keenest Budget Bureau official could not suspect that "Appliance for milling wooden dowels up to 10 millimeters in diameter, as per sample" meant a pencil sharpener, or the "Instrument for recording test data with rotating roller as per sample" meant a typewriter . . . And if there was nothing else to do, we entrenched ourselves behind the magic word "secret." There, the Budget Bureau was powerless.*

Slowly they were able to build a facility that was usable.

Building and Testing Real Rockets

The first rocket engine built by the Kummersdorf team was a liquid-propellant motor using ethyl alcohol and liquid oxygen.

They worked fast and by December 21, 1932, it was ready for its first static firing test.

Over the centuries, people have used the word "rocket" interchangeably to mean both an object powered by rocket power and the engine that powers the object. In recent years, to avoid confusion, it has become more common to talk about the "rocket engine" in discussing the power source that propels the vehicle, leaving the word "rocket" to mean the vehicle propelled by a rocket engine. A rocket can carry a cargo as well as its fuel and engine—and that cargo may be a warhead, in the case of a weapon, or scientific equipment, or anything else that the rocket engine is powerful enough to transport. The more powerful the rocket engine, the bigger the cargo it can propel, and the farther it can take it.

This rocket engine could not have carried much of a cargo. It was only 20 inches (50.8 cm) long, consisting of a pear-shape combustion chamber made of aluminum. The team had placed it on a stand in the center of a testing room, lit by floodlights. Walter Riedel was in charge of the valves that controlled the flow of fuel and liquid oxygen (LOX) to the engine's combustion chamber. Located behind the test site's 13-foot (3.9-m) concrete walls, which were covered with a movable roof of tar paper and wood, Riedel probably stood in the safest position. Heinrich Grünow stood nearby, with his eye on a pressure gauge. His job was to control the valve that governed the pressure in the fuel tanks. To von Braun, standing at the open end of the test bay, fell the unenviable task of igniting the engine, using the most primitive and dangerous of methods—an "igniter" consisting of a 13-foot (3.9-m) wooden pole with a can of flaming gasoline attached at one end. Dornberger watched from a distance of little more than 90 feet (27.4 m), protected by the slender trunk of a pine tree.

The orders echoed in the night air: *"Feuer! Benzin! Sauerstoff!"* (Fire! Gasoline! Oxygen!). Von Braun swung the flaming can of gasoline under the rocket nozzle, while Riedel opened the fuel and oxygen valves.

An eerie white cloud seeped from the nozzle and spread to the ground, followed by a slender trickle of alcohol. Suddenly it came in contact with the flames from the gasoline can, ignited with a *swoosh* and a hiss, then a loud crash. As Dornberger described it:

Clouds of smoke rose. A single flame darted briefly upward and vanished. Cables, boards, metal sheeting, fragments of steel and aluminum flew whistling through the air. The searchlights went out.

Silence.

In the suddenly darkened pit of the testing room a milky, slimy mixture of alcohol and oxygen burned spasmodically with flames of different shapes and sizes, occasionally crackling and detonating like fireworks. Steam hissed. Cables were on fire in a hundred places. Thick, black, stinging fumes of burning rubber filled the air. Von Braun and I stared at each other wide-eyed. We were uninjured.

They were lucky. The test stand was demolished, metal doors torn off hinges, steel girders and pillars twisted and bent. But no one was hurt, although shards of sharp steel were embedded high in the trees overhead. It was their first effort, and their first failure. Many more explosions, failures, and disappointments would follow in the years to come—they were working on the cutting edge of a new and complex technology, and many factors had to balance, through trial and error, before success would be theirs.

Three weeks later a new rocket design was ready to test. After igniting successfully, the whole rocket engine burned with a white-hot heat: The aluminum of the combustion chamber jacket had caught fire. It was the Kummersdorf team's first cooling problem.

Under Dornberger's guidance, the team also tested combustion chamber designs and fuel-injection systems. The fuel injector on a rocket works a lot like a fuel injector on an automobile, spewing a fine spray of fuel or LOX into the combustion chamber, where it ignites. The fineness of the sprays and the mixture of fuel to LOX had to be exactly right, and trial and error were the only teachers in this new field.

The team also tested the flow and mixture ratios of fuel and LOX as well as various types and combinations of fuel. They measured the temperature of the exhaust flame, and they sampled the exhaust to determine its makeup. Under Dornberger's meticulous guidance, von Braun, Riedel, Rudolph, Grünow, and the others who joined them had begun to do rocket engineering in earnest.

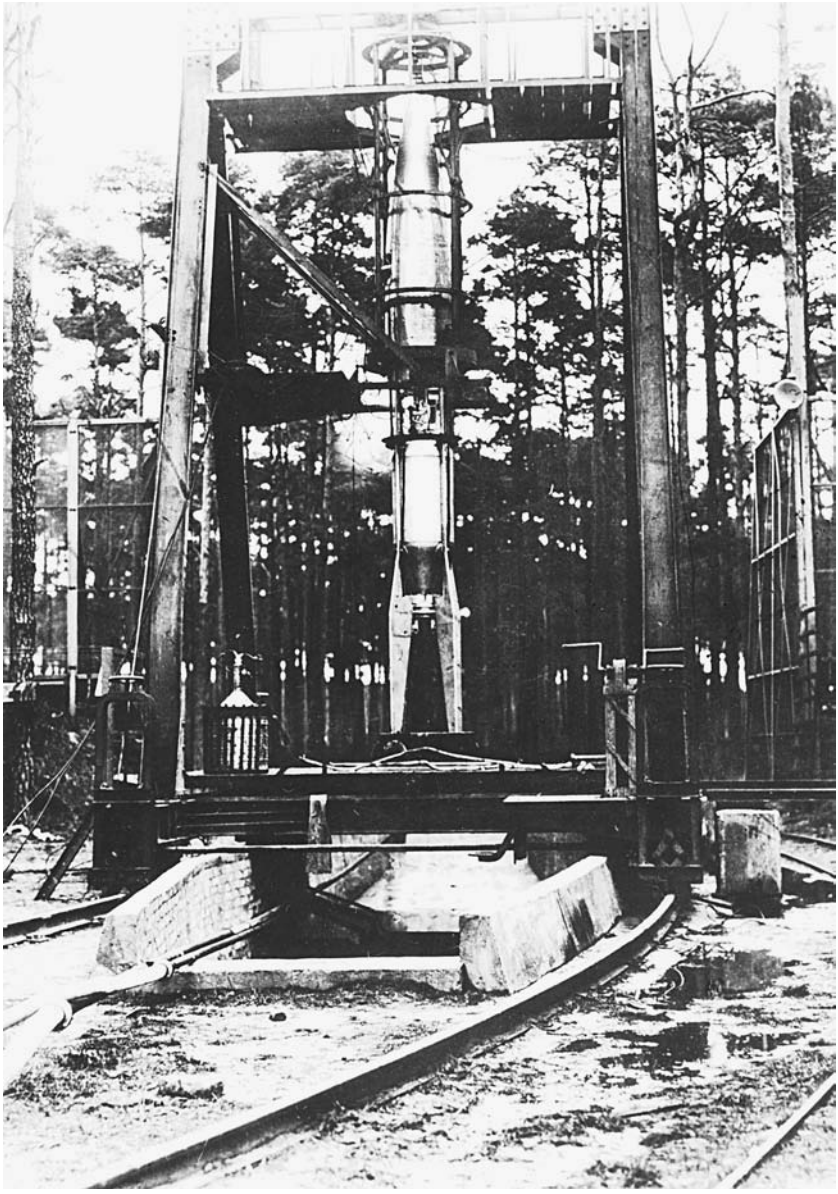
Finally the time had come to put together their first rocket for flight, an *aggregat,* that is a rocket-engine assembly. For the Aggregat 1, known as the A-1 for short, the objective was to build a liquid-fuel rocket that would fly reliably and hold to a prescribed flight path. It was a tall order.

The men knew they would have to deal with the issues that had kept the Mirak II from flying straight, but no one in Germany knew any more about it than they did. For some reason, the design for the A-1 included no fins. Probably the best explanation for this design decision is that the army and Dornberger—an artillery expert—thought of the rocket as a gigantic flying shell. A shell is stabilized by its spin in flight. But spinning the entire body of a rocket would send the liquid fuel spinning around the walls of the tanks, making control of its flow into the combustion chamber almost impossible. So, at Dornberger's suggestion, the team members decided to put a gyroscopic spin on part of the rocket, to be located in the nose cone. The rotating nose section of the A-1 weighed 85 pounds (38.5 kg), without its payload (cargo). The entire rocket measured only 55 inches (139.7 cm) and was just under a foot in diameter. In two tanks it carried alcohol and liquid oxygen, with a third tank for pressurized nitrogen, which the team used to force the propellants into the combustion chamber.

In more sophisticated systems developed later, a gyroscope would often be used to provide a frame of reference (keeping track of which direction is up) for a guidance system, which in turn uses robotlike devices to move vanes and fins to adjust the flight path and steer the rocket. In this case, the spinning section of the rocket was supposed to do the whole job all by itself, simply by the force of its spin.

It did not work. It is easy now to scoff and wonder why the scientists did not at least add the obvious stabilizing factor that fins would provide. Arrows use feathers to fly a straight path. Why not fins along the shaft of a rocket? But these men were working on the front lines of this technology, trying what no one had ever tried before.

Von Braun and the team scrapped the A-1 and went on to a new design, Aggregat 2. This rocket, which was the same size as the A-1, used a new engine design that could deliver 2,205 pounds (1,000 kg) of thrust, compared to the puny 661 pounds (299.8 kg) supplied by the A-1's engine. Von Braun and Rudolph, at least,



Rocket testing began in the early 1930s at Kummersdorf, as shown in this photo taken about 1932–33 of an A-2 on one of the several test stands located there. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

were still thinking in terms of developing rockets for space travel, even though they had been hired to develop weapons. For that, they would have to move up to bigger and bigger engines and, ultimately,

bigger and bigger rockets. In the A-2, von Braun also had moved the gyroscopic portion of the rocket—still functioning on the same principle as before—from the nose cone to the midsection. Now their rocket would no longer be top-heavy.

The team built two A-2s, which they named Max and Moritz, after the Katzenjammer Kids, popular comic strip characters at the time. They took Max and Moritz to the island of Borkum in the North Sea for launch. And they flew! Both reached an altitude of about 1.2 miles (6,000 feet [1,981.2 m]); von Braun, Rudolph, Riedel, and even Dornberger were jubilant.

Growth of Nazi Power

Meanwhile, trouble for Germany and for the world at large had been brewing. The Nationalist Socialist German Workers' Party (or Nazis) had begun to gain more and more ground among the discontented electorate in Germany. By 1930 the Nazis had gained 18 percent of the vote in the elections to the Reichstag (the German equivalent of Congress or Parliament), their strength second only to the Social Democrats. On January 28, 1933, the chancellor, Kurt von Schleicher, resigned, after unsuccessfully attempting to form a coalition government, and two days later the Nazi party's leader, Adolf Hitler, was appointed to take his place. Less than a month later 40,000 men were sworn in as auxiliary policemen. Five days after that, on February 27, a fire broke out in the building that housed the Reichstag in Berlin. It was all the excuse that Hitler needed. (And, in fact, some historians claim his henchmen set the fire.) He blamed the Communists and dissidents for this attack on the heart of German democracy, and the following day he was given emergency powers that virtually made him dictator of Germany.

The Nazis won nearly 45 percent of the seats in the Reichstag in the elections held a few days later, and in the following days Hitler began to gather around him one of the most deadly groups of men in world history. Step by step he cemented his position of power, with the formation of the soon-dreaded SS (Schutzstaffel, or Black Shirts, a quasi-military police arm with enormous power); the establishment of special courts for the prosecution of political enemies; his stripping of power from individual states; the national boycott of Jewish businesses and professionals; and the formation of the Gestapo, his

secret police force. On October 14 Germany withdrew from the League of Nations, signaling an end to the nation's attempt to bend to the demands of the world community. Before long it became clear that Germany was headed for war.

Under the Nazis, the army paid less and less attention to provisions of the Versailles Treaty and began openly developing weapons such as big guns and cannons. But the activity at Kummersdorf also began to step up. Although no longer needed as a way around the Versailles Treaty, the ballistic missiles that von Braun and his team were developing could serve a purpose that long-range artillery could not.

Airplanes Powered by Rockets

Meanwhile, the army was not the only German military service that saw uses for rocketry. While the army saw rockets as sort of huge artillery shells, the Luftwaffe (the German air force) became interested in adding rocket power to its propeller-powered airplanes, and turned to the army for help. Dornberger and von Braun saw no problem with this plan—they signed a contract, took on the job, and von Braun set about creating a design.

Static testing began in 1935, and by 1936 the work was ready for testing with a human pilot aboard. The Junkers aircraft company delivered a small, wingless fuselage, called a "Junior," to Kummersdorf. The Kummersdorf team mounted the Junior on a huge centrifuge and installed a rocket motor with a thrust of 661 pounds (300 kg) on its belly. On the other end of the long arm the scientists installed a counterweight.

Von Braun, always fascinated with flying, was especially drawn to this project. He had begun his first gliding in 1931, taking lessons at the famous Wolf Hirth's Soaring School in Grunau in Silesia. By 1933 he also had taken flying lessons and had become a licensed pilot. Later, from 1936 to 1938, he would serve two hitches in the military as a pilot in the prewar Luftwaffe, when he received pilot's ratings on heavier fighter planes, such as the Stuka and the Messerschmitt 109, and for multiengine aircraft.

So when a human pilot was needed to test the Luftwaffe's "Junior," von Braun climbed into the cockpit, strapped himself in,

and signaled ignition. After he whirled around at a breathless 5 gs, the spinning stopped and he climbed down. Although pale and dizzy, he was enthralled at the success. The Kummersdorf team had achieved another milestone. They had proved that rocket power could be used with human-piloted aircraft for bursts of power and speed.

In about 1935, the Luftwaffe also became interested in an extension of this idea. Often a heavily loaded propeller-driven airplane would have trouble taking off with its cargo, although it would be fine once it was airborne. The Luftwaffe asked the Kummersdorf team to design and build rocket engines to give a heavily laden plane the boost it needed on takeoff. But to build and test on this scale, von Braun saw that they would need more room. So he and Arthur Rudolph went to the German Air Ministry with a proposal. The army and the air force, they said, should establish a joint rocket development base that would have the kind of space and facilities required by the new projects. To their delight, the idea was greeted warmly.

And so Dornberger and von Braun began looking for a bigger, better place to build and test rockets—somewhere isolated and flat, with lots of wide, open space to minimize the danger to nearby citizens. Somewhere on the coast, where test rockets could be shot over the water and parallel along the coast so that their progress could be monitored visually and reported by radio; somewhere that could be kept secret.

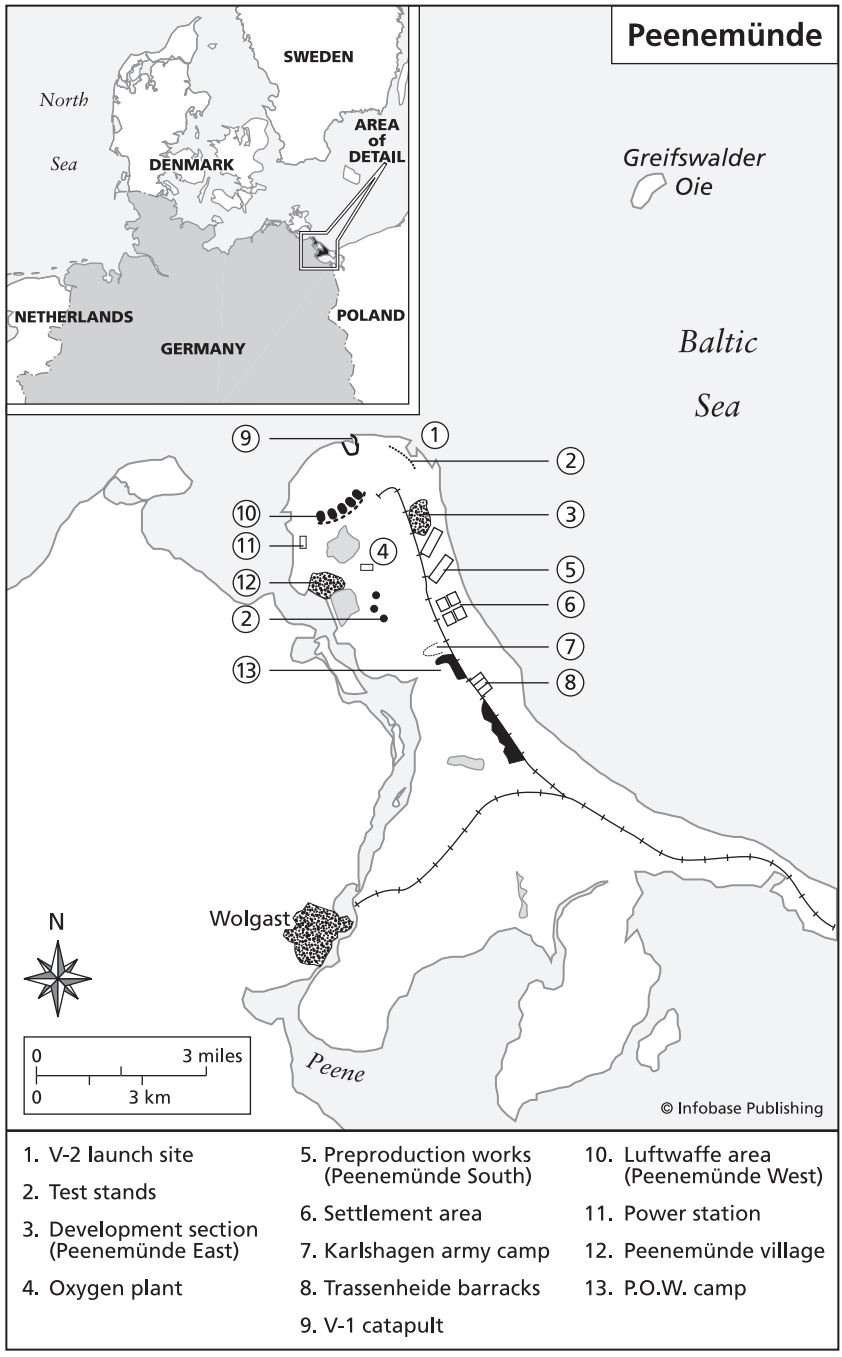
While visiting his parents at the family estate in Silesia in Christmas 1935, von Braun mentioned the search. Why not look on the island of Usedom, near Peenemünde, his mother suggested, where your grandfather used to hunt ducks? The idea seemed worth looking into.

5

Grazing the Edges of Space

Peenemünde was located on a spit of land jutting out into the Baltic Sea from the northwestern tip of Usedom Island, due north of Berlin. Peaceful and isolated, it had few inhabitants—just acres of pinewoods, rolling sand dunes, and marshes populated by many varieties of water fowl. Von Braun fell in love with the place immediately and brought Dornberger around for a look. Hidden away, yet with a clear shot along the coastline, it was perfect for the needs of the Kummersdorf team.

Usedom, along with the neighboring island of Wollin, extends along the northern edge of Stettin Lagoon, separating its waters from the Baltic Sea. From the mainland, four rivers empty their waters in that area and wend their way around the sprawling islands and into the Baltic: the great Oder River to the east, the Randow, the Uecker, and the Peene, which empties toward the western end of Usedom



Peenemünde was an isolated island on the North Sea, providing a spacious area for the German army's expanding rocket development and testing.

and flows in a channel between the island and the mainland, northwest to the sea. Near its mouth lies the tiny village of Peenemünde, literally, "mouth of the Peene."

The Case for Peenemünde

Dornberger saw that the Kummersdorf research might profit from the rivalry between the army and the newly formed air force. The Luftwaffe wanted rocket-powered takeoff capability for its airplanes. The army, in turn, wanted to offer a long-range artillery capability as an alternative to air force bombing missions, which risked the loss of valuable pilots and crew members, required extensive training, and ran up the bills.

Dornberger and von Braun played this advantage to the hilt. In March 1936 Dornberger invited Major General Wernher von Fritsch to visit Kummersdorf. Von Fritsch was commander in chief of the Reichswehr. If he was impressed, they thought, support could be theirs. When he and his staff arrived, Dornberger and von Braun went into action, with von Braun making the kind of persuasive presentation that would become his trademark. He had colored charts and graphs; he had models; he had diagrams; and he had his charismatic personality. Never known to be struck with stage fright, von Braun had an extraordinary power to gain and hold the attention of his listeners, pull them into his world and fill them with his enthusiasm. Throughout his career he mesmerized diplomats, business tycoons, presidents, and generals.

After the verbal presentation, Dornberger and von Braun took the general on a tour of the rocket test stands, where they demonstrated the Kummersdorf team's 660-pound (300-kg), 2,200-pound (1,000-kg), and 3,300-pound (1,500-kg) liquid-fuel rocket motors in static tests. The sheer noise and power of the demonstrations struck awe, and von Fritsch succumbed. "How much money do you want?" he asked. It was von Braun's first big success in the arena of political persuasion.

The Wehrmacht and the Luftwaffe held a joint meeting in Berlin in 1936 and, in what Dornberger later called an "attack of acute generosity," General Albert Kesselring, chief of aircraft construction, gave his approval for the purchase of the island of Usedom for use

by the two services. The Luftwaffe agreed to build a rocket test site at Peenemünde, with two sections, Peenemünde-East for the army and Peenemünde-West for the air force. The Wehrmacht and the Luftwaffe would split the expenses of operating the site.

By the end of 1936 the quiet of Peenemünde was broken by the sounds of men sawing down trees, steam shovels digging out roots, and huge earth-moving machines leveling the dirt for construction. The great rocket development center had begun to take shape. By the time it was finished in 1939, it would have its own power plant, an oxygen-generating plant, test stands, bunkers, barracks, and a wind tunnel for testing the aerodynamics of rocket designs. To the south, the pre-production works were housed in two big concrete sheds, nestled among the evergreen trees and camouflaged by netting.

On the western side of the island, the Luftwaffe built Peenemünde-West, where the development would continue on the air force's Fieseler Fi-103, an unmanned cruise missile or plane, which later became known as the V-1, or "buzz-bomb." There, also, the army's

Von Braun shows officers of the German army the facilities at Peenemünde. Von Braun is the civilian on the far right, front row, wearing a trench coat and rain hat. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

rocket team would continue building several rocket motors for assisting the Luftwaffe in improving airplane takeoffs.

Peenemünde-East would become the development site for the ballistic rockets that the army's team had begun to develop at Kummersdorf. By 1942 Dornberger would have more than 1,960 scientists, engineers, and technicians under his command as well as another 3,852 support personnel. By mid-August 1943 there would be 17,000 personnel altogether. And the military would pour more than 300 million deutschmarks (about $70 million) into the construction at Peenemünde.

There von Braun and the rocket team would complete their work on the world's first long-range ballistic missile. It would become the first weapon of its kind designed for mass production on an assembly line. It was the first truly large missile, incorporating engineering advances that would provide the prototype for big rockets developed after the war. The Peenemünde team's aim was to develop a military weapon, but the men knew this work would become the basis not only for intercontinental ballistic missiles (ICBM) but for spacebound rockets as well. They were working on the vanguard of rocket technology, in a world all their own. And the pressure was cranking up.

A-3: High Hopes Frustrated

Meanwhile, back at Kummersdorf, as the A-2s were being readied for testing, the rocket engine team had been working on an even more powerful engine, the 3,300-pound (1,500-kg) motor, which had 50 times the thrust of any rocket seen up to that time. With the financial backing of the military, the German team had moved far ahead of similar developments in the rest of the world. This new engine placed the dream of flying into space within reach.

By December 1937 the A-3 was ready for a test flight. Despite wretched weather, von Braun and members of his team headed out to the tiny island of Greifswalder Oie, north of the new rocket center being built at Usedom. There they prepared to launch three test rockets. They had no launch tower, just a bare concrete surface, and they had no range control facilities for tracking the missiles once launched. So they spent days waiting for everyone to get into

position—radio operators to track the launched missile, recovery aircraft, and divers. Finally on December 4, 1937 all was ready.

The first A-3 was launched. Five minutes after liftoff, the parachute deployed, and the rocket went offcourse. The second A-3 was launched without a parachute. This one crashed as well. Von Braun decided to wait for the blustery winter weather to calm before sending the last A-3 aloft, but to no avail. The third rocket also went awry.

Disappointed, von Braun returned to Kummersdorf determined to learn everything he could about gyroscopes and flight stabilization. He and his team set about correcting the stability problem and some of the other snags in the A-2 and A-3 in a new test rocket they called the A-5. This rocket would test new stabilization systems devised by von Braun himself. Meanwhile, a much more ambitious project was also afoot: the A-4.

A-4: Even Higher

The A-4 was the first rocket to be built to specific performance specifications; earlier rockets were built and then tested to see how well the new design performed. A few days after General von Fritsch's visit in March 1936, Dornberger had sat down with Riedel and von Braun to outline his plans. They were developing artillery, he reminded them, for use in battle, and if they didn't come up with something useful, funding would dry up. He set out specifications for the next rocket, the A-4: It must have twice the range of the Paris Gun, a total of about 162 miles (260 km); it must be capable of carrying a warhead weighing 2,204.6 pounds (1 metric ton); it could deviate only 6.5–10 feet (2–3 m) from its target; it must be transportable by rail or roadway to any point within German boundaries (limiting its length and diameter to sizes that would pass through tunnels and go around curves in roads and railways).

One by one the members of the team faced and met the challenges. The team had grown between 1936 and 1939, with Dornberger and von Braun making several important additions to round out

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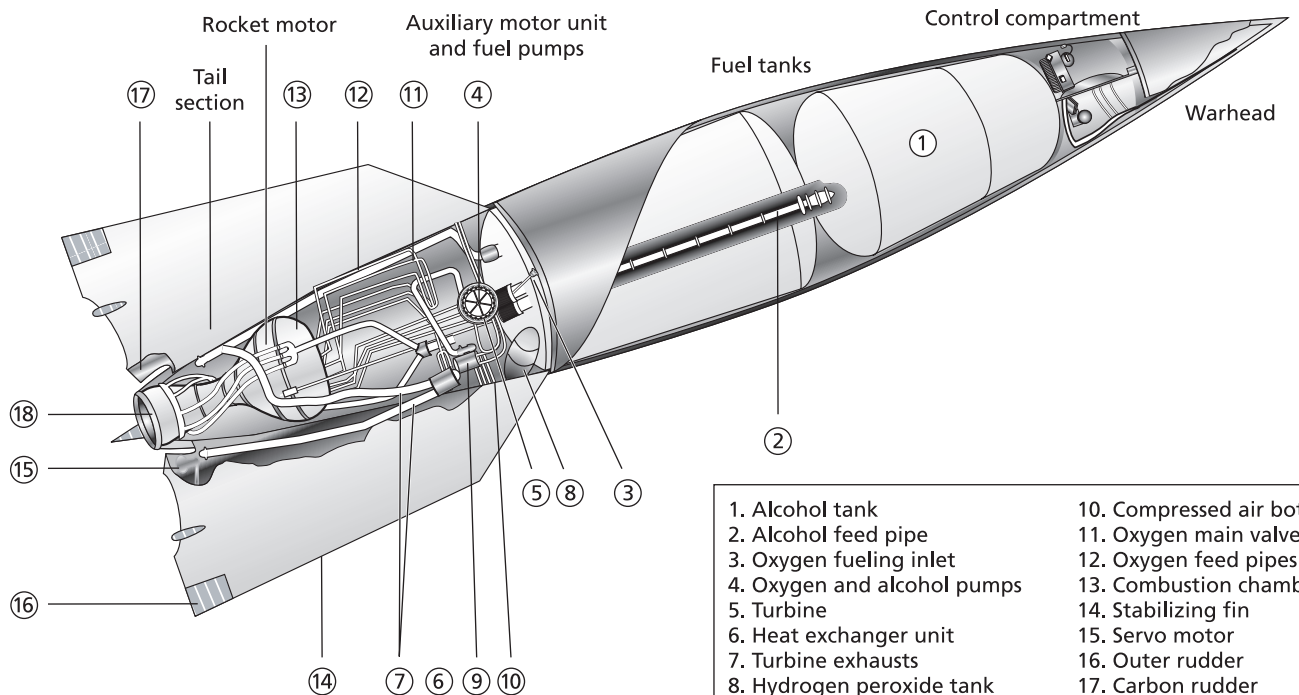
(Opposite page) *Cutaway view of the German A-4 Rocket. Note the warhead located in the nose of the A-4 rocket. The rocket itself is not a weapon; it is simply a means of transportation. However, the Nazis were interested in the potential of the A-4 (later renamed the V-2) to deliver a bomb from a site on the south side of the English Channel north to London. It was the first long-range strategic missile.*

Cutaway View of the German A–4 Rocket



1. Alcohol tank
2. Alcohol feed pipe
3. Oxygen fueling inlet
4. Oxygen and alcohol pumps
5. Turbine
6. Heat exchanger unit
7. Turbine exhausts
8. Hydrogen peroxide tank
9. Sodium permanganate tank
10. Compressed air bottles
11. Oxygen main valve
12. Oxygen feed pipes
13. Combustion chamber
14. Stabilizing fin
15. Servo motor
16. Outer rudder
17. Carbon rudder
18. Thrust ring

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its technological strengths. Among them was Walter Thiel, a tense, ambitious, and brilliant engineer who combed his blond hair slicked straight back and wore horn-rimmed glasses. Thiel worked hard and was scrupulously conscientious. With his addition to the team, von Braun no longer had first-line responsibility for engine design, although he and Dornberger continued to brainstorm ideas with Thiel. By improving the mix of fuel after injection—thereby improving the overall efficiency of the rocket motor—Thiel succeeded in increasing the all-important exhaust velocity by 5 percent.

Dornberger suggested recessing the injectors, which worked well, and Thiel began clustering the injectors to increase power. Von Braun contributed the idea of placing 18 injectors in two concentric circles at the front end of a large combustion chamber. Another colleague suggested a cooling method for the throat of the nozzle, which tended to heat up and burn through with the passage of the hot exhaust gases. The new method involved using a film of alcohol to cool the metal in that area. These innovations combined to produce a truly reliable liquid-fuel rocket engine for the first time.

Most of the team moved to Peenemünde in May 1937, while Thiel remained behind at Kummersdorf until 1940 to continue his work on the engine.

But there was still more work to be done. The team needed to improve the fuel pump, and the specifications seemed impossible. It needed to be light in weight, fast reacting, simple in construction, and capable of delivering high volumes of fuel. Von Braun frequently made business trips flying himself in a Messerschmitt Typhoon. He could be anywhere in Central Europe within an hour or two, and he liked to visit manufacturers to obtain help with problems like this one. The answer this time was a fire-fighting pump, found at a pump factory, off the shelf and already in production.

Team members also found they could power the pump using high-strength hydrogen peroxide combined with a permanganate solution to produce a high-temperature, high-pressure steam to turn a turbine.

The aerodynamic problems did not respond immediately to this kind of brainstorming, however. To try out the stability of different fin arrangements and shapes at supersonic speeds, Dornberger had had the foresight to negotiate for the construction of a wind tunnel

Hitler (center, turning), who had established himself as dictator in 1933, visited at Kummersdorf in 1939 to see the army's advances in rocketry. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

at Peenemünde, but it was one of the last buildings to be completed. Rudolph Hermann, a specialist in aerodynamics, was brought in from the Technical University at Aachen to consult on both the wind tunnel construction and the rocket's aerodynamic design. However, the final design decisions for the A-5 and, later, the A-4 were reached on the basis of tests made not in a wind tunnel but by dropping test flight vehicles from Heinkel He-111 bombers at 20,000 feet (6,096 m). By the time the test vehicles had fallen to about 3,000 feet (914.4 m) above the ground, they had reached supersonic speeds, and their behavior could be observed and filmed. Finally, the design engineers settled on an automatic pilot that was stabilized by a gyroscope, which in turn controlled air vanes on fins and jet vanes in the rocket exhaust.

During these days, von Braun spent evenings with his old friend Hanna Reitsch, who had taken advanced gliding lessons with him at Grunau in 1932 and had since become Germany's foremost female aviator. She often performed test flights for the Luftwaffe at Peenemünde-West, and when she did, she and von Braun would meet for dinner and conversation. He enjoyed her zest for life and relished comparing notes about flying, which they both loved.

Hitler Visits

But the politics of building rockets proved to be far more complicated than either the technology or von Braun's social life. Both von Braun and Dornberger recognized that a project the magnitude of the A-4 development would not survive without the support of Hitler himself. So they were very pleased when, on March 23, 1939, Hitler came to visit.

Hitler did not, however, go to the new rocket center at Peenemünde, but opted for a look at rocketry closer to the capital, at Kummersdorf. Although people often have talked about "Hitler's rockets," Germany's leader was not a great fan of rocketry or most technologically advanced weapons. He felt that jet planes moved too fast for combat, and he deplored tanks as cowardly. But Dornberger and von Braun knew that, more and more in Germany, no project could flourish without Hitler's support. And whatever he opposed was as good as finished.

Adolf Hitler: Monster Unleashed

Germany's defeat at the end of World War I in 1918 left the citizens of Germany both financially impoverished and humiliated from severe blows to their national pride. Many people were left hungry and angry. To this provocative mix of emotions came a strange but charismatic young man who gave Germany back its sense of national pride and hope for the future. He also gave them someone to blame: the Jews, gypsies, and homosexuals—any non-Aryan or unwanted group, but especially the Jews. Adolf Hitler became chancellor in 1933, and he began to implement his plans for a rise to absolute power.

Already by 1933, Hitler had laid the groundwork. In 1925, the SS (*Schutzstaffel* or "defense echelon") was founded as a special security force to form Hitler's personal bodyguard. This group attained increasingly broader powers in the years to come. Another group, the Gestapo storm troopers (*Geheime Staatspolizei* or secret police) was formed in 1933, at the very beginning of Hitler's reign of power. He also moved immediately to gain control of all news media and communications. Newspapers and radio were routinely censored and even movies and plays were controlled.

When Hitler arrived with his entourage, he seemed preoccupied, his thin lips pressed together beneath his little black mustache. Dornberger and von Braun began with the test stands, always a stunning display. But the 660-pound (300-kg) motor made no impression. Neither did the big 2,200-pound (1,000-kg) motor. Then von Braun gave a briefing on the A-5, using a cutaway model. As usual, he was at his best, careful not to insult or bore the Führer with too much detail, yet offering enough to whet his well-known interest in intricate machinery.

What kind of payload could this missile carry? Hitler wanted to know.

Von Braun explained that the A-5, a test vehicle, was not designed to carry any payload, but that larger rockets, based on this research, could be built to carry substantial military warheads.

How long would it take to develop such a vehicle? For this question von Braun deferred to Dornberger's military expertise.

Persecution of the Jews began immediately. By February 1933 a decree gave the government the right to arrest individuals without cause. Jewish families, gypsies, homosexuals, suspected opponents of Hitler's Nazi party, and others considered a drain on Nazi power disappeared in the night, arrested and dragged off to concentration camps.

The Nazis began to remove Jewish administrators from official positions. Synagogues and Jewish shops were attacked and burned. People were terrorized in their homes and gassed or starved in concentration camps. Jews were required to wear yellow stars to identify themselves. Many people, Jewish or not, began to leave their homes and careers behind in Germany as they fled.

In 1939, Hitler invaded Poland in a flagrantly aggressive move, and conditions in Germany continued to worsen. Yet Hitler's grip on the nation's destiny seemed ironclad and unyielding, and many people both in Germany and elsewhere did not even seem to know what was going on.

"With our present level of effort, and with our present budgetary support, it will take considerable time," Dornberger responded carefully. Maybe, he thought, Hitler would see fit to increase the support.

But Hitler only nodded curtly.

Even the finale, a static test of the huge 3,300-pound (1,500-kg) motor, belching out its thunderous roar, didn't seem to move him. Later, over his usual mixed vegetables and glass of mineral water, he concluded, *"Es war doch gewaltig!"* ("Well, it was grand.") To the rocketeers, this odd comment, though apparently a sort of praise, seemed unenthusiastic and anticlimactic. Hitler, it seemed, was not overly impressed.

A "Secret Weapon" for War

On September 1, 1939, German armies invaded Poland. Two days later, on September 3, Britain and France declared war on Germany, and World War II had begun. By 1942, Germany's opponents would be joined by the United States and the Soviet Union, which, with Britain, France, and China, became known as the Allies.

On September 19 Hitler announced in a speech that Germany was working on a "new secret weapon," referring to the rockets, and for a brief time General von Brauchitsch gave the rocket makers the highest possible priority. Prior to the invasion of Poland, construction at Peenemünde, though nearly completed, had slowed almost to a standstill. The Luftwaffe had threatened to withdraw funding, and it looked like plans for the rocket center would fall through completely. But that autumn Albert Speer, the inspector general of construction for the Nazis, was placed in charge of completing Peenemünde. A favorite of Hitler's, Speer later confessed that he liked working with the young rocket team and von Braun, then 27, whom he described as "purposeful, a man realistically at home in the future." The work in rocketry, he said, "exerted a strange fascination upon me. It was like the planning of a miracle."

By the fall of 1939 most of the rocket team, with the exception of Thiel, had transferred their work from Kummersdorf to Peenemünde. Living quarters were completed, and the wind tunnel was almost ready. But the rocketeers were stunned to hear suddenly, as the year rolled to an end, that funding had been cut back

again. Triumphant from an easy victory in Poland, Hitler had grown confident that the "secret weapon" would be unnecessary and had changed his mind. It was the first of a series of roller coaster funding cutbacks and infusions.

Luckily for the future of rocket development, Speer stuck by the team, despite Hitler's directive. As Speer admitted after the war, "By tacit agreement with Army Ordnance Office, I continued to build the Peenemünde installations without its approval—a liberty probably no one but myself could have taken."

On June 13, 1942, the first A-4 was ready to fly. Armament chiefs from three branches of the armed services arrived to witness the test, along with Albert Speer. Dornberger, von Braun, and the team, all equally tense, gathered with the dignitaries to watch.

The rocket stood four stories high, commanding sober attention, a huge and improbable giant. As the fuel tanks were filled, wisps of vapor whirled into the crisp air.

The moment came. The beast seemed to tremble and then falter. Then with a deafening roar, the unleashed giant rose slowly upward. It seemed to pause for a moment, as if standing on the sword of its flame, and then shot upward, all 12 tons, with a great howl, into the low-hanging clouds. Von Braun's expressive face broke out in a beaming grin.

A minute and a half later another great howl told the startled observers that the rocket was falling back to Earth—quite nearby—plunging to the ground only half a mile (0.8 km) away.

In fact, the guidance system had failed—the stability system had not kept it from turning into the wind—but the great deed had succeeded: The mammoth beast had gotten off the ground. Corrections were made to the guidance system, and a second test was made on August 16, but again the rocket flew erratically. More work still had to be done.

Finally, on October 3, 1942, everything seemed ready. This time Dornberger watched from behind the protective brick parapet surrounding the roof of the Measurement House at Peenemünde, far enough from the launch site to be safe, but close enough to see.

"Would the launching be successful this time?" Dornberger found himself thinking. "Had we really discovered the cause of failure of the last two attempts . . . ?" Ten years had passed since the

team members had started out on this long path. Would they find success at last?

Countdown. Ignition. And the big rocket lifted straight up toward the sky as members of the team shrieked with delight.

"It looked like a fiery sword going into the sky," team member Krafft Ehricke would recall years later. "And then came this enormous roar. The whole sky seemed to vibrate. This kind of unearthly roaring was something human beings had never heard."

The A-4 arced through the sky, reaching up toward the fringes of space to an altitude of 60 miles (96 km). The rocket builders were standing, they recognized, on the precipice of a new age; like Magellan and Columbus, they had sighted vast new worlds.

"This is the key to the universe," Dornberger is said to have exclaimed with great excitement. "This is the first day of the space age!"

Even Dornberger, as von Braun liked to tell it, had become infected, despite his military priorities, with the enthusiasm for space that his engineers all privately harbored.

In fact, they had produced a 12-ton (10.8–m tons) missile that had traveled a distance of 120 miles (192 km), under automatic control, landing within 1.5 miles (2.4 km) of its target. "We have thus proved that it is quite possible," Dornberger told the team in a congratulatory speech, "to build piloted missiles or aircraft to fly at supersonic speed, given the right form and suitable propulsion. Our self-steering rocket has reached heights never touched by any man-made machine." In military terms, they had broken the world altitude record established at 24 miles (40 km) by the Paris Gun.

"We have invaded space with our rocket," Dornberger continued, "and for the first time—mark this well—have used space as a bridge between two points on Earth; we have proved rocket propulsion practicable for space travel. To land, sea, and air may now be added infinite empty space as an area of future transportation, that of space travel . . . So long as the war lasts, our most urgent task can only be the rapid perfecting of the rocket as a weapon. The development of possibilities we cannot yet envisage will be a peacetime task."

On December 22, 1942, Speer convinced Hitler to sign orders authorizing the mass manufacture of the rocket, which Hitler began to see as the potential answer to all his military woes. However, in March 1943, a new blow was delivered to the A-4 development. The always-erratic Hitler had dreamed, he said, that the rocket would never be operational against England, and he removed support from the project.

Nonetheless, on July 7, 1943, Speer invited Dornberger and von Braun to visit Hitler in his headquarters at the Führer's request. It had been four years since their last meeting, Germany had achieved no quick victory and the war was going badly. After a wait of several hours, finally the doors opened and a herald stepped forward with the Nazi salute and a cry: *"Der Führer!"* But there was something eerie about the leader when he entered the room. As Dornberger would later write:

> *I was shocked at the change in Hitler. A voluminous black cape covered his bowed, hunched shoulders and bent back. He wore a field-gray tunic and black trousers. He looked a tired man. Only the eyes retained their life. Staring from a face grown unhealthily pallid from living in huts and shelters, they seemed to be all pupils.*

But von Braun was confident, filled with his usual boyish enthusiasm. Assistants from Peenemünde showed a film of the great A-4 rocket launch, the huge missile rising from its pad and disappearing into the clouds. It was the first rocket launch Hitler had ever witnessed.

He suddenly grew animated, jumping up, asking questions. He was won over. Hitler promoted Dornberger to general and conferred the honorary title of "professor" on von Braun. He even apologized to Dornberger for not having believed in him.

"The A-4 is a measure that can decide the war," he confided later to Speer. "And what encouragement to the home front when we attack the English with it! This is the decisive weapon of the war."

Hitler's reaction was another stunning turnaround. But in some ways this new enthusiasm was worse than Hitler's prior disbelief in

rockets. Now he was counting too heavily on the A-4 for powers it did not have.

In fact, it would not be the weapon to reverse the tide, the great thundering hope from the skies. The decision to pour resources into the A-4 rocket had come too late. For one thing, the A-4 was an experimental rocket, still a long way from being ready for production.

And yet another strike against the A-4's progress was about to descend, from out of the blue.

6

Peenemünde's Last Days

The moon was full on the night of August 17, 1943. It beamed out over the waters of the North Sea along the coast of Norfolk County on the easternmost edge of the British Isles like a great searchlight. Destroy "at the first favorable opportunity," the orders to British Bomber Command had read. And now the hour had come.

Wing Commander J. H. Searby took off at 9:50 P.M. from the Norfolk coast, flying southeast toward the Baltic Sea with his six-man crew in their Lancaster. Behind them followed 597 other Royal Air Force (RAF) Lancaster bombers and Halifax heavy bombers. It would be a long trip, and dangerous, since it was too far for the usual protective fighter planes to fly alongside as watchdogs. On this mission they were on their own. Sixty crews had not returned from a

similar Allied bombing mission earlier that same day. This mission must be critical, Searby knew, or the RAF would never risk so many men at such unfavorable odds.

A flight of small Mosquito bomber planes had gone ahead, flying over Peenemünde without pausing as they streaked toward Berlin to feint an attack on the capital. The ruse worked. German defense aircraft followed them, drawn away as Searby and his bombers headed toward their mark. The pathfinder planes flow over the little island spit, dropping colored flares to signal the targets, Searby leading the way. As they zeroed in, finally the German antiaircraft defenses kicked in. They had grown wise to the diversionary tactics, but not before the British bombers were on their mark—and their mark was Peenemünde.

Night of Fire

In Peenemünde that night, Dornberger had put out his after-dinner cigar and left the Hearth Room early. The conversation with aviator Hanna Reitsch, their guest that evening, had naturally drifted to flying. He had no real interest in the subject; it had been a hot, humid, trying day; and he was tired. As he made his way to the guest house where he usually stayed when he came up from his office in Berlin, he heard an early-warning siren. Peenemünde was usually secure—with good camouflage, nightly blackouts, and night fighter planes and antiaircraft guns at the ready. But that night the moon was full. He quickly phoned air defense headquarters to check on the warning. The reply was uncertain: Allied aircraft were massing in the central Baltic, but the status was unclear. Bombers often flew overhead en route to Berlin. This was probably just another foray of the kind that had become almost commonplace in recent days. Dornberger went to bed.

Von Braun, by this time the technical director of the Peenemünde rocket center, stayed a little longer to finish his conversation with the others. Then he walked Hanna Reitsch to her car. She would head over to Peenemünde-West, where she was scheduled as test-pilot on an Me163 rocket-powered plane the next day. He bid her good night and good luck and strolled to his own quarters, a dormitory where several bachelors lived.

Ernst Steinhoff, director of rocket guidance and control, who was also with the group that night, headed home to his family in the residential settlement, where many of the engineers and their families lived on the Baltic. Dornberger was jolted awake in the middle of night by the shattering of window glass as it sprayed across his bed and the sound of antiaircraft fire. He bolted from bed, grabbed his slippers, threw on his uniform tunic over his pajamas, and raced out. When he arrived at the air raid shelter, von Braun and between 50 and 100 other people were already there. Dornberger took charge immediately. He phoned the chief air-raid warden and received confirmation: They were in the midst of a full-scale attack. He set von Braun to work organizing a salvage party at the construction bureau. Every scrap of paper and machinery that could be saved had to be removed from the burning buildings.

Von Braun and others ran out into the inferno, surrounded by helpers covered with grime, sweat, and soot from the explosions. They dodged chunks of flaming debris and jumped gaping potholes as they made their way to the building that contained everything they had been working on, von Braun's life's work for the past 13 years.

His secretary, Hannelore Bannasch, later wrote in her diary about that night: "Everywhere I look it's fire. Fire, everywhere fire—horrible beauty!"

She and others rushed to the building that contained von Braun's office. The roof had already collapsed, but the stairway was still passable. What once were office doors now were completely unrecognizable. They fumbled their way to the room that was once his office, pressing tightly against the one remaining wall. The rest of the room had collapsed. They grabbed a safe and the files, stacks of them—as much as they could carry—and raced down the stairs, trip after trip, stashing them in the safe. Von Braun and some of the men threw equipment and files from the windows, while Bannasch gathered the papers into the safe outside as the fires raged around them. Finally the job was done and the most important documents had been rescued.

When at last the gunfire and bombing blasts grew quiet and the roar of airplane engines stilled, only the crackling flames filled the night. The British bombers had hit, and they had hit reasonably well. They also had paid a price. When Searby led the way back to

The RAF attacked Peenemünde on the night of August 17, 1943, causing extensive damage to the rocket development facility. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

England, 40 planes—and with them their crews totaling 240 men—were missing from the formation.

The next morning von Braun flew a plane overhead to take a look from the air. The place looked devastated, like the cratered surface of the Moon. Dornberger assessed the damage on the ground. The streets of Peenemünde were strewn with rubble, buildings blackened by blasts and steel girders twisted like pretzels. But not all was lost. Von Braun and his crew had saved the all-important blueprints. The test stands, wind tunnel, and Measurement House all stood unscathed. Of the 735 people killed in the attack, most were construction laborers—Russian prisoners of war and Polish slave laborers. Among the 178 German technicians killed, however, was the indispensable engine designer Walter Thiel, recently moved to Peenemünde, whose house was hit while he and his family slept.

Setbacks for the A-4 Rocket

But the bombing had a devastating, though less direct, effect on the center and its work. As a result of the raid, it was obvious that

Peenemünde was no longer a safe place to amass all the aspects of rocket development. Facilities were moved quickly to more dispersed locations. The valve lab was moved to Ankham, 19 miles (30 km) to the south, and again, to Friedland, 42 miles (68 km) from Peenemünde. The materials testing lab was moved to a vacant warehouse at Sadelkow, 43 miles (70 km) south. By September the ground support equipment team—which was working on a launcher and a transporter—moved to two abandoned railway tunnels near Bonn, 358 miles (575 km) to the southwest. And by November the supersonic wind tunnel was disassembled and shipped to the Bavarian Alps. Whereas once the managers could visit all the shops under their jurisdiction every day, traveling by bicycle, now their charges were scattered all over the map of Germany.

Most telling of all, test launches were moved to Blizna, Poland, for the moment beyond the range of Allied bombers, and production was moved out of Peenemünde completely. As a result, Dornberger, who had been engaged in a subtle power struggle to maintain control of the A-4's development and production, stood to lose the battle.

Dornberger first had begun to lose control when Hitler had ordered the A-4 into production in December 1942 at the unreasonable rate of 2,000 per month. From the beginning, Dornberger had planned to produce as many A-4s as possible at the pre-production plant he had built at Peenemünde South. But on January 8, 1943, Speer thwarted that plan by appointing as production engineer Gerhard Dengenkolb, who took production out of Dornberger's hands.

In any case the A-4 was not really ready for use in the field, much less for this pell-mell production schedule. No one had even thought about building ground support equipment or methods of deployment in the field, and developing the necessary equipment and systems would take more than a year. Also, the A-4 was an experimental rocket with a lot of bugs, or imperfections, still uncorrected. Each A-4 up to this point had been hand-built, and each one had 90,000 parts. Before the end of the war more than 60,000 design changes would be made *after* it was placed in mass production.

Following Hitler's visit with von Braun and Dornberger in July 1943, when the Führer suddenly began to see the A-4 as his "miracle weapon," the Peenemünde team was really placed in a bind. They were now expected—after months, even years, of cutbacks and

delays—to produce a unique scientific instrument ready for production under wartime conditions. Throughout Germany Allied bombers now strafed industrial complexes and destroyed suppliers. The Allied armies advanced closer daily. And shortages made every step of production more difficult.

A sinister political squeeze had begun to play in the picture also. Even before von Braun and Dornberger's meeting with Hitler, Heinrich Himmler, the chief of the SS, had appeared one day in April 1943 at Peenemünde. Dornberger thought the visit was odd, SS security was responsible for guarding the rocket facilities, but beyond that the SS ordinarily had no jurisdiction on this joint army and air force installation.

But Himmler had been polite and had listened well as he looked through his pince-nez at the rocket test stands and the development facilities. When he left he said quietly, "I am extremely interested in your work. I may be able to help you. I will come again alone. . ."

Although the man had a reputation for extending his power through hard-line tactics, Dornberger did not worry at first. Then, Colonel Leo Zanssen, a friend who had been a station commander at Peenemünde for years and a steady and reliable career officer, was suddenly dismissed. Himmler himself had inexplicably brought charges against him. According to other friends, rumors among the SS officers blamed Dornberger for the delays in A-4 development.

Himmler came back, on June 29, driving himself in a little armored car. On this occasion he commandeered the attention of von Braun, Dornberger, and several other Peenemünde staff members for a five-hour lecture after dinner on the purposes of the war, history, and philosophy. The next day he saw two test launches of the A-4. The first failed, but the second flew beautifully. Himmler offered to put in a good word with Hitler for the rocket staff's work and left.

Production and Secrecy Mount

From the earliest development stages, one of Hitler's great concerns was that secrecy about the new weapon must be maintained. Now, after the raid on Peenemünde, the matter seemed all the more urgent, and for this, Himmler placed SS brigade general Hans Kammler in

charge of rocket construction during the summer of 1943. Now, for the first time, the SS had made inroads into army territory. Kammler was also the SS officer Dornberger trusted least. Known to be devious, meddlesome, and even vicious, he undermined the team spirit and played Peenemünde workers against each other, even commenting once to Dornberger that von Braun was "too young, too childish, too supercilious and arrogant to be technical director."

Kammler had access to concentration camp laborers in his capacity as chief of SS construction, and he had a plan: Make use of prisoner-slave labor and no news of the "secret vengeance weapon" could possibly leak out.

Horrors at Mittelwerke Factory

An assembly plant was established at Mittelwerke, an underground factory tunneled into the Harz Mountains in southern Germany. Production of subassemblies and components began there in August 1943, and the first missile rolled off the assembly line that winter. On January 27, 1944, for the first time, a Mittelwerke missile was fired up for testing. It was an abysmal failure. Furthermore, the projected production was way behind schedule. Of the 650 planned to come off the assembly line in January, only 50 made it. Obviously the Mittelwerke production process still had a long way to go. Some 5,000 contractors and subcontractors in industry provided parts and systems to the Mittelwerke production initially, but as German industry suffered from Allied bombings, more and more of the work was moved to the dank underground tunnels of Mittelwerke.

There, and in other factories, Himmler's concentration camp inmates—totaling more than 30,000—were forced to work under incredibly inhumane conditions. By 1944, over 10,000 prisoners were at work in Mittelwerke alone, many of them making a forced march daily at 4:00 A.M. from the camp at Nordhausen. From another camp at Dora, the prisoners marched through a tunnel connected directly to the factory. Sanitary conditions were abominable, and both disease and starvation were widespread. Thousands died at their work as a result of their treatment, their corpses piled up unburied and rotting by the time Allied troops later discovered the camps.

During these years most of the rocket scientists, including von Braun, knew about the conditions under which the slave laborers worked. Later von Braun remarked, "The working conditions there were absolutely horrible. I saw the Mittelwerke several times, once while these prisoners were blasting new tunnels in there in what was a pretty hellish environment." He also told writer Arthur C. Clarke that he did not thoroughly inform himself about the conditions at Mittelwerke, "But I suspected it, and in my position I could have found out. I didn't, and I despise myself for it."

Heinous persecution and wholesale slaughter of Jewish citizens had already been going on for years under Hitler's regime. During the same years the rocket team was struggling for funding to keep their program alive, the Nazis stepped up their persecution of Jewish citizens, as well as other groups considered "unworthy," including gypsies, homosexuals, and certain Catholics. Auschwitz was established as a concentration camp in 1940, after Poland's defeat, and by 1941 the first Jews and other victims began to arrive at what had by then become designated an extermination camp. Between 1 million and 4 million people died there in gas ovens and by other methods during the next four years.

What could von Braun have done about any of this? Probably very little. Generally, those who crossed Hitler and his henchmen paid with their lives and brought about no change. But many other Germans refused to cooperate and fled the country. Granted, leaving Germany in 1944 might have been difficult and certainly dangerous for the leader of the A-4 rocket development team—strategically he was very valuable to Hitler by this time. But it would not have been impossible. Von Braun, however, was wedded to his vision.

He later claimed that press censorship by the Nazi regime made the atrocities much less visible from within the Third Reich than from the outside. "I never realized the depth of the abyss of Hitler's regime until very late and particularly after the war, when all those terrible abuses were first published," he later wrote. Not seeing, or not looking, was an irreversible act for which many would hold him responsible throughout his life.

Meanwhile, the SS net continued to close around the work at Peenemünde. In February 1944 Himmler called von Braun in for a conference. No doubt, Himmler proposed, Peenemünde's technical

director was fed up by this time with army red tape and bureaucracy. Things could go so much smoother if Himmler were in charge, instead of Dornberger. Why not throw in his lot with the SS? Himmler suggested to von Braun. Then progress on the A-4 could really take off, with Himmler personally clearing away the bothersome political obstructions.

Taken aback, von Braun answered carefully but firmly that no one could hope to find a more excellent administrator than Dornberger. Any slowdowns encountered by the A-4 were caused by technical difficulties, not red tape, he assured the SS chief. He tried to conclude the meeting gracefully, and as he left, Himmler seemed at least polite. Von Braun returned to Peenemünde and threw himself back into his work, putting the strange meeting out of his mind.

Dreaded Knock in the Night

At 3:00 on the morning of March 13, 1944, von Braun was wakened in his quarters by a curt knock at the door. Three Gestapo agents told him brusquely to dress and come with them to the Polizei Präsidium in Stettin. They had orders, they said, to bring him in for "safekeeping."

Von Braun had no idea what this "safekeeping" could mean—safekeeping from what, and why? He protested that surely there must be some mistake. But, in the end, it became clear he had no choice.

"I languished in the SS jail in Stettin for two solid weeks," he would later recall, "without the slightest information from the authorities as to the reasons for my arrest."

Finally he was brought, without explanation, before what appeared to be an SS tribunal. He was accused, they told him, of having said that he never intended the A-4 to be used as a weapon and that he had designed it for use in space travel. In fact, just a few nights before his arrest von Braun had been talking at a party about the rocket's potential for exploring space, as he often did. Yet the attitude was common among those working at Peenemünde. But that was not all, the SS continued. He was planning to escape in his airplane to England, with important data about rocket building. Von Braun would later remark to a *Life* magazine reporter, ". . . Himmler arrested me and accused me of keeping the plane gassed up so I

could fly off to England with the V-2 [modified A-4] secrets, which was pretty absurd."

But at the time, the accusation struck him as chilling. He *was* in the habit of keeping his plane gassed up, for his frequent trips around Germany. If the SS wanted to interpret this fact as treason, how could he defend himself?

At that moment, Major General Dornberger marched in and presented the SS officers with a document, which they read immediately. The next thing von Braun knew, he was released and striding out of the police station with Dornberger. To von Braun it seemed like a miracle.

In fact, Dornberger's miracle was the result of two solid weeks of frantic work. Von Braun was not the only one arrested in the March 13 sweep in Peenemünde. The Gestapo also had scooped up Klaus Riedel and Hermann Gröttrup.

Dornberger had heard the news with a shock the next day, after being called to Hitler's headquarters in Berchtesgaden (in the Bavarian Alps in southeastern Germany), where he had orders to meet with Field Marshal Wilhelm Keitel of the Armed Forces High Command.

"I could not believe my ears," Dornberger would later recall. "Von Braun, my best man, with whom I had worked in the closest collaboration for over ten years and whom I believed I knew better than anyone, whose whole soul and energy, whose indefatigable toil by day and by night, were devoted to the A-4, arrested for sabotage! It was incredible." The arrests of Riedel and Gröttrup seemed no less insane.

He appealed to Keitel. The matter was beyond him, Keitel explained, in Himmler's hands. If he tried to step in, the army's last liaison with Hitler would be gone, the only protection against the SS's rapidly widening control would be rubbed out. Suddenly Dornberger began to see the smoking gun. So that was it. Himmler was making his move for complete control of the A-4.

He asked to see Himmler. He was refused. But he did get a chance to see SS General Hans Kaltenbrunner at the SS Security Office. These three men, Dornberger asserted firmly, were vital to the A-4 program. Progress could not proceed without them. In the process, Dornberger was informed (probably to intimidate him) that

the SS also had a fat file on *him.* Speer would later claim that von Braun and his colleagues were released through *his* intervention, rather than Dornberger's. Quite likely the efforts of both men had an effect. In any case, the three rocket men were released provisionally for three months, and at the end of that time the adjournment was renewed.

Bigger and Better Rockets

During the years 1943 to 1944, von Braun continued working on new designs—including a rocket he called A-7 and two others that he called A-9 (also known as the A-4b) and A-10. The A-9 and A-10 were intended to work together as a multistage rocket—an idea anticipated by both Tsiolkovsky and Oberth—with the A-9 boosted by an A-10, producing a projected range of some 3,200 miles (5,120 km). For the first time, practical engineering was done on the idea, and this multistage rocket, if completed, would have been able to strike New York City.

While Germany never developed that capacity, the A-4 became a weapon of terror in London and Antwerp during the years from 1944 to 1945. The first attacks on September 8, 1944, took England completely by surprise. The last of the dreaded attacks by the Luftwaffe's V-1 "buzz-bomb" (*Vergeltungswaffe 1,* "Vengeance Weapon #1") had dwindled off during the summer, and British officials had declared the "war of terror" at an end at last.

But the sigh of relief was premature. The armed A-4, or V-2 (*Vergeltungswaffe 2,* "Vengeance Weapon #2"), as Hitler's propagandists called it, was in some ways worse than the V-1. It seemed to come from nowhere, and it plunged straight to Earth, striking all the way to the basements of buildings, where the din of its explosion rocked everything for miles and whole rows of houses were taken out. By the end of war, the Germans had manufactured between 5,789 and 6,915 V-2s, and 3,225 landed on targets in England, France, Belgium, and elsewhere. The V-2s killed over 2,700 people in England, seriously wounding many more. In Antwerp, a single rocket caused 271 deaths, and many thousands of homes and buildings were destroyed.

Von Braun's Conscience

Perhaps, when he first became a civilian employee of the army, von Braun had not imagined his rockets would really be used as weapons. But no such case could be made for him later, when "Hitler's rockets" became Nazi "vengeance weapons." Wernher von Braun was a pragmatic man who had seen a way to achieve his goals and followed the path with focus and discipline. When the time came that his progress might be hampered because he was not a member of the Nazi party, he joined the Nazi party, and, with Peenemünde under SS control, he also became an SS officer, according to FBI records collected later.

Von Braun had his own agenda—never losing sight of his original vision of building space rockets, which he talked about openly and often (at least once too often). But he also never seemed to regret the use made of his work, in contrast to many American scientists, such as Robert Oppenheimer, who admitted to deep anguish when the atomic bomb they had created was used against citizens in the cities of Hiroshima and Nagasaki. For this apparent lack of conscience, von Braun came in for criticism throughout his later life. But his personal ethic called for singleness of purpose and discipline, for performing his best, and for keeping commitments. He may have regretted that he had not informed himself about the workers at Mittelwerke, but on the subject of rocket development, he felt he had performed only with honor.

Should von Braun, then, have acted differently? The SS was right about one thing—he could have used his gassed-up plane to fly away. Thousands of others did leave, including Albert Einstein and von Braun's old friend Willy Ley. But to von Braun, the thought was "absurd." His attitude let him in for criticism worldwide as a proponent of "science without conscience" or, as a popular satirical song of the 1960s put it, "'Once the rockets are up, who cares *where* they come down/That's not my department,' says Wernher von Braun."

In the end, the V-2 did not vanquish the English. If anything, the huge rockets strengthened their resolve, and they came back fighting harder than ever. Soon the Allies had Germany in a great pincer, the British and the Americans coming from the West, the Soviets advancing from the East. France was retaken, then Belgium. The

Allied bombers strafed any areas from which they thought the V-2s could be launched, and soon the Germans were forced to retreat from almost all areas that were within the V-2's 200-mile (124-km) range from England. From Peenemünde, the sounds of the Soviet guns could be heard in the all-too-near distance. By the end of 1944, the handwriting was on the wall: Germany would not win the war. The time for decisions had come.

7

Operation Paperclip

As the days marched into 1945, Soviet guns approached nearer and nearer to Peenemünde. Polish refugees began to stream across the island of Usedom, instead of crossing the Oder River at its mouth, as a shortcut in their efforts to escape the Soviet troops pressing them from the east. Old people pushing wheelbarrows filled with their belongings trudged hopelessly through the snow. Young women and children huddled together against the cold. The tales they told of rape, murder, and pillage at the hands of the Soviets did nothing to brighten the Peenemünde team's vision of the future. Orders came down from the German army command to stand and fight, but everyone knew that rocket scientists would make poor opponents for trained Soviet soldiers and their weapons. However, the SS had arrested and shot several engineers who had been heard saying so and hung their bodies as examples from trees along the

busy roadways. Signs with large letters made the point: I WAS TOO COWARDLY TO DEFEND THE HOMELAND.

The Allied forces in Europe, meanwhile, were pushing the German troops out of the areas from which they had been launching V-2s. The Peenemünde team was increasingly pressed to increase the V-2's range, without slowing the production schedule. Shortages and inferior quality of component parts slowed the work markedly, and von Braun sent his brother Magnus to Mittelwerke to see what he could do to expedite production. In Peenemünde, transportation, supplies, and communications became increasingly critical issues, while ration stamps, black-marketeering, and complaints became rampant. The evidence of the damage done to German industry mounted daily.

By August 1944, Himmler had appointed Hans Kammler to a new post, placing him in charge of all A-4 development and manufacture. Although Albert Speer protested that this move infringed on his territory, the overlapping authority had remained in place, and the iron fist of the SS clenched all the more firmly around Peenemünde and its crews. Dornberger was shunted off to Berlin for another project. In part to divert Allied intelligence from suspecting that Peenemünde was still operational, the installation was renamed Elektromechanische Werke (Electromechanical Works) and became a civilian, state-owned industrial firm with a general manager Paul Storch effectively taking Dornberger's place. Although Storch was in charge, he deferred in all technical matters to von Braun, who remained on the scene as technical director. Von Braun, however, had neither the power nor the influence to evacuate anyone or anything from Peenemünde, and the SS appeared to have no thoughts of evacuation.

Then on January 31, 1945, von Braun called in his section chiefs and department directors.

Darkening Dangers from Within

"Kammler has just ordered the relocation of all the most important defense projects into central Germany," he said in a strained voice. "This is an order, not a proposal."

Now that the order had come from Kammler, somehow it seemed suspect. Why was he massing all the defense projects in central Germany? In a way, it seemed like a reasonable plan: Mittelwerke

was there, and if the Allies were pressing in, Germany could then consolidate forces in an effort to stand them off. But von Braun suspected Kammler had other motives in mind, perhaps wanting to gather some pawns to play in his favor when the time came to surrender to the Allies. And von Braun knew he did not want himself and his men to be part of such a plan. Another possibility was that the SS was seeking to eliminate everyone who might be useful to the enemy; they could be walking into a deadly trap. However, at the moment, he seemed to have no choice.

At 8:00 the morning of February 3, von Braun held another meeting. Slated for the move were 4,325 people. "But we will go as an organization," von Braun asserted. "This is important. We will carry our administration and structure straight across Germany. This will not be a rout."

One hundred trucks were loaded with equipment and files. Barges were loaded on the river, and train cars were packed.

They moved out by night for the 250-mile (400-km) journey south, with the first trainload departing on February 17, 1945, less than three weeks after Kammler's orders had been received. More than 500 technicians and their families were on board.

Chess Game with Fate

By mid-March only a skeleton crew was left at Peenemünde. The test stands and launch sites stood empty. Altogether, 264 developmental launchings of the A-4 had been fired between June 13, 1942, and February 19, 1945. An era had come to an end.

As his engineers and technicians began arriving at their destination in the Nordhausen-Bleicherode area, von Braun pressed ahead with developmental work on more advanced rockets, since the A-4 now seemed to be a lost cause. He set up the experimentation sites in the underground Mittelwerke factory, or wherever he could in unused garages and empty buildings.

The tension and ceaseless activity were exhausting, not only for von Braun, but for his crew. On a road trip, his driver fell asleep at the wheel, crashing the car and fracturing von Braun's arm and shoulder.

Then more bad news. On March 19, Hitler, recognizing that defeat was near, ordered the SS and the army to destroy everything

of possible value to the approaching enemy forces. By March 21, von Braun had argued his way out of the hospital and began planning to save the 65,000 V-2 drawings and tons of blueprints and documents from what became known as Hitler's "scorched earth" policy—even though ignoring the Führer's orders could mean big trouble with the SS.

He asked Dieter Huzel, his personal assistant, and Bernhard Tessman, who had saved him days before from the wrecked automobile, to gather up all the V-2 technical documents, load them on trucks, and find a hiding place.

Then on April 1 the danger to the Peenemünde rocket specialists became especially ominous. Kammler had decided he would retreat with 500 of von Braun's key scientists and engineers to the Bavarian Alps. They could continue their research at an old army camp at Oberammergau, and they would be protected by a special SS detachment.

Kammler claimed that his plan was connected to a scheme of Hitler's to regroup with key SS divisions in a place 400 miles (640 km) south, known as the Alpine Redoubt. From there they would make a stand and emerge victorious. But von Braun felt sure that Kammler was actually executing his own plan to play a deadly game of chess using the Peenemünde men as pieces. Of course, disobeying Kammler's orders could still bring immediate execution, so they went to the Alps, with von Braun hoping he would have a chance to save his team. Dornberger, meanwhile, was able to position himself in a village close by with a detachment of army soldiers who were under his command.

On April 4, von Braun arrived in Oberammergau. The camp in which his men were billeted was surrounded by a barbed-wire fence, and, as each day passed, he worried about what would happen as the scene played out. By April 10, work had stopped at Mittelwerke, and the 4,500 technicians who remained there were dispersed to the surrounding villages. By April 12, the Nordhausen area was in the hands of American troops.

For months, as the war drew to a close, independent intelligence teams from each of the Allied countries had been jockeying to secure German weaponry, engineering designs, and brainpower. Preparing for postwar animosities, each country hoped to get away with the

most and gain the greatest advantage, once the regions of Germany opened up. Now the Mittelwerke factory's V-2s and V-2 parts had fallen neatly into the hands of Americans, who immediately set about locating more and tracking down the documents Huzel and Tessman had hidden. The soldiers managed to dig them out of the mine they were stashed in mere hours before the British moved in.

As the German rocketeers watched the Allied forces press in on them, they debated about which nation would be most advantageous to surrender to, if given any choice. They settled on the Americans. When later asked why, one member of the rocket team explained, "We despise the French, we are mortally afraid of the Soviets, we don't believe the British can afford us, so that leaves the Americans."

But von Braun and all the key people were still 400 miles (643.7 km) away, in grave danger and in no position to surrender to anyone.

Then suddenly Kammler summoned von Braun to a meeting. The conversation between them in a local tavern was strange. Kammler asked how von Braun's men were, how they took the transfer, and whether they had resumed their all-important work for the future. He then explained that he was leaving to tend to other duties. Final victory, he assured von Braun, was still attainable. That was all, dismissed. Von Braun never saw him again.

The next day von Braun took advantage of Kammler's departure to convince the major who had been left in charge that concentrating all these valuable minds in one place was not a good idea. A single hit could destroy the men who had created the Third Reich's greatest technical triumph. Better they should be dispersed in the local villages. His persuasive, telling arguments won the day, and he and Ernst Steinhoff, the Peenemünde director of guidance and control, succeeded in moving the men out from behind the sinister barbed-wire fence.

About April 25, von Braun was roused from his sleep by a German army soldier with a Red Cross armband. He was whisked away to a hospital, where his arm was reset, and then transported to the village of Oberjoch near the Austrian Tyrol. There, at a hotel, he found Dornberger, his brother Magnus, and several others of his rocket team colleagues. Dornberger had gathered as many of his rocket experts as he could, hoping to protect them if necessary against the SS with the 100 men he had at his disposal.

By May 1, word arrived that Hitler had committed suicide. The end, they knew, was finally at hand.

Seeking Capture

The following day von Braun sent Magnus off on a mission, through the snowy woods, on his bicycle. Magnus von Braun's instructions were to find the Americans and tell them where Dornberger, von Braun, and the rest were located. But when he finally encountered an antitank unit on the lonely country road, they didn't believe him at first. They took Magnus in for questioning. Later that afternoon, when Magnus brought his rocket colleagues in under safe conduct from the U.S. Army and the Americans met Wernher von Braun, the group was still deeply skeptical that this energetic 33-year-old man could be the famous German rocket genius. This man, they thought, was too young, too fat, too jovial.

Von Braun (center, with cast) talked persuasively at the time he and his team surrendered to the U.S. Army and convinced them that the German rocket team would be a great asset. (NASA Marshall Space Flight Center)

But quickly the word was passed to a group of American agents who had been charged for months with finding this select group of Germans whose names had been placed on what was known as the "Black List." The British, French, and Soviets had put together much the same list, but it was the American army that had undramatically come into possession of these important human "spoils of war."

The Americans were elated at their find. Colonel Holger N. "Ludy" Toftoy, U.S. Army Ordnance Corps, moved quickly to negotiate to bring as many of the German scientists and engineers as he could to the United States. Whichever nation succeeded in enlisting their help, he reasoned, could begin where the German experts had left off, instead of "reinventing the wheel." Although the V-2 had not won the war for Germany, if it had been developed earlier, it might have. And if an atomic warhead (which Germany had not developed) had been added, the V-2 would have been devastating.

Initiating "Paperclip"

In a semicovert operation known as "Overcast" (renamed "Operation Paperclip" in 1946), Toftoy enlisted von Braun's help in choosing the best group of irreplaceable scientists and engineers from his team.

Von Braun and the others underwent extensive interrogations in Garmisch and Paris, all the while being propositioned by the Soviets to walk out on the Americans and come over to their rocket program. Only one of them did—Hermann Gröttrup, who had been arrested by the SS with von Braun and Riedel in 1944. According to his wife, who later published her diary of their years with the Soviets, he lived to regret the choice. The Soviets promised the German rocketeers that they would be allowed to work in Germany and then virtually kidnapped them and their families and whisked them away to the Soviet Union. They were never trusted and spent much of their time at test sites in desolate Siberia. As von Braun remarked in 1957, "The Russians let them see nothing, touch nothing on the production end, learn nothing from developing experience, just had them write reports until they were drained dry. Then the Russians went on by themselves." By 1957 not one of the German rocket scientists and technicians who went to the Soviet

Walter Dornberger's Deal

Walter Dornberger almost saw his deal with the British backfire. The British wanted to keep him to stand trial on charges as a war criminal for his role in the use of the V-2 weapons. Although Dornberger protested and von Braun contributed testimony, Britain kept him for two years, finally releasing him in recognition that he, in fact, had no jurisdiction over the firing of the V-2s. Dornberger finally arrived in the United States in 1947 and accepted a position with Bell Laboratories, where he completed his career.

Union was still there. They all either had died or had been sent back to East Germany.

The British had also succeeded in gathering up V-2s and V-2 parts, and in June 1945 von Braun proceeded to London "on loan" to help the British with questions they had about their V-2 rockets. Several other rocket specialists, including Walter Dornberger, also were part of this "loan." While the German scientists were in England, the British tried to entice many of them to give up the contracts they had signed with the Americans and stay to help them with their rocket programs. The deal was attractive—London, was a lot closer to home, and the British promised to put them up in posh hotel accommodations. Von Braun and the rest were cordial but didn't take them up on their offer, returning to Paris on schedule.

Back in Paris, Toftoy finalized arrangements for von Braun and 114 others from the team to leave for the United States. In mid-September, just over four months after surrendering in the Bavarian Alps, Wernher von Braun's plane took off for what would become his new home, where he would begin a new chapter in rocket history.

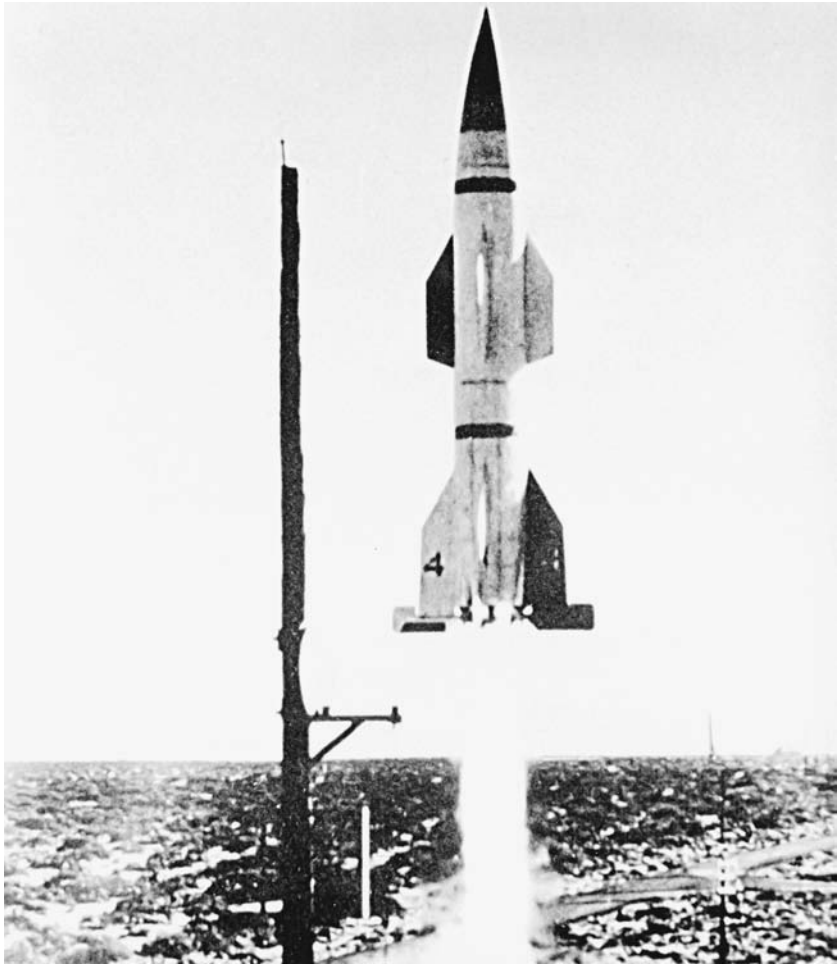
8

V-2s in the United States

In the spring of 1945, trainloads of strange cargoes began wending their way into the desolate desert regions of southern New Mexico to a place called White Sands. The cargo contained fully assembled, V-2 rockets, as well as parts and materials for building them.

Not long afterward 115 German engineers, technicians, scientists, and mechanics followed to a nearby army installation in Fort Bliss, Texas. Fort Bliss was in the far northwest corner of Texas, just north of El Paso, where the Rio Grande separates the United States from Mexico and a jog in the border of New Mexico accommodates the north Texas border. It would become home to these men who had become a strange sort of war booty.

As a result of military orders from the supreme Allied commander, General Dwight D. Eisenhower, Wernher von Braun arrived in the United States by air in mid-September 1945, along with



The U.S. military was quick to begin learning about its newly acquired arsenal, as indicated by this 1945 launch of a Hermes A-1 missile—built from German parts shipped from Europe. (NASA/NACA)

several other top members of his rocket team. He reported first to Fort Standish in Boston, Massachusetts. From there he proceeded by boat to Fort Strong, on New York's Long Island, where he and six other German rocket scientists underwent long hours of interrogation. To pass the time when the Army Intelligence Service wasn't questioning them, they played games of Monopoly far into the night.

At this point many of von Braun's colleagues were sent to work at the Aberdeen Proving Grounds in Maryland, sorting and interpreting

14 tons (12.7 m tons) of notes and documents that they had produced while developing the German rockets. The task was arduous and tedious. Eisenhower's original orders read, "Upon completion of this duty, the civilians named below will return to their proper station in this theater." Most of them, however, never did return to their homeland, except to visit.

On October 3, 1945, the U.S. Army Ordnance Corps activated a sub-office for rocket development by creating a technical unit located at Fort Bliss, Texas, and placed Major James P. Hamill in command. From Long Island, accompanied by Hamill, Wernher von Braun set out across the country by rail for Texas. On the way, for his own protection, Hamill encouraged von Braun not to mingle with other passengers. Memories of the war and lost loved ones were all too recent in the minds of Americans, and his fellow passengers would hardly have welcomed the news that they were traveling with a former Nazi.

The Rocket Team Arrives

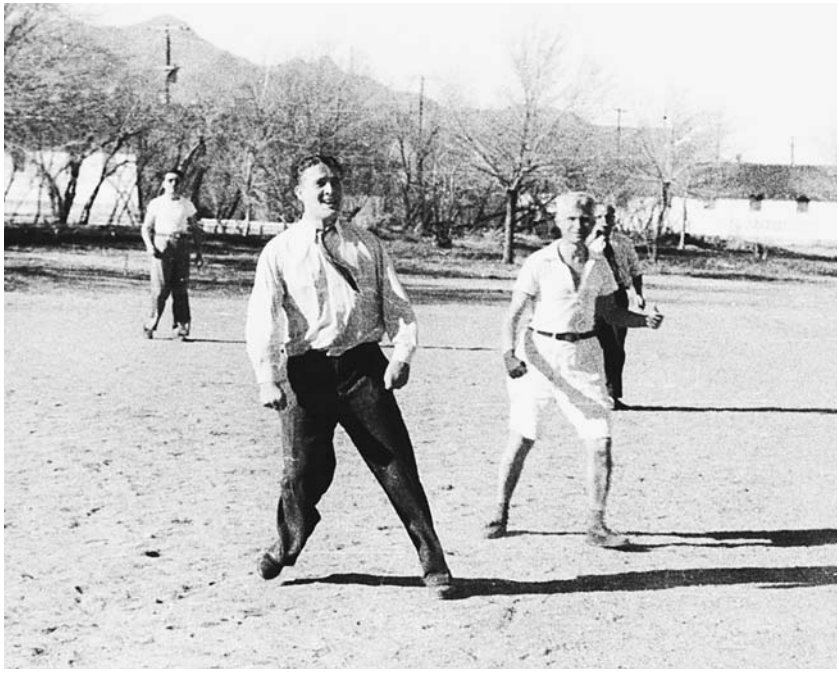
In Fort Bliss, von Braun was soon reunited with most of his handpicked German rocketeers. Their job was to put together and test

Operation Paperclip brought about 100 members of von Braun's team of scientists and technologists to Fort Bliss, Texas, by the end of 1945. (NASA, Marshall Space Flight Center)

the V-2 rockets and rocket parts that had arrived from Germany, as part of a project named "Hermes," shared by General Electric and the U.S. Army. While the German rocket specialists hoped they would be able to continue the work in space rocketry that they had begun, at that time, no one in the United States was thinking in those terms yet.

For the most part, the five years at Fort Bliss were years of isolation for the German rocket team. They were not allowed opportunities to meet with American engineers to talk shop; nor were they allowed to attend scientific conferences or read journals in their field. Their lives were carefully structured, controlled, and isolated. On weekends, small groups of five or six were allowed to go into town, in the company of an army escort, to shop, have dinner at a restaurant, or maybe see a motion picture.

In those early years, some segments of the U.S. government kept the rocket specialists under constant surveillance. Each specialist



Von Braun continued to cultivate teamwork at every opportunity and always saw himself as part of "The Team," on the job or off—as he does here, playing ball at Fort Bliss. (Archives, U.S. Space and Rocket Center, Huntsville, Alabama)

was assigned an army custodian, who kept a security dossier on him and was responsible for his whereabouts and activities at all times.

In addition, the Germans received low pay, had an uncertain future, and underwent separation for many months from their families. Colonel (later Major General) Toftoy, Major Hamill, and von Braun somehow convinced the team that all these problems were worth putting up with for the sake of an opportunity, nebulous and uncertain as it must have seemed. As rocket engineer Ernst Stuhlinger later recalled, "After all, we came here to help develop rockets and we wanted to do that."

Toftoy once remarked that von Braun "held his team together through many years of adversity," which he was able to do because the rocket specialists knew what they had already accomplished as a team. They knew that von Braun could bring out the best in them—and they counted on having the opportunity to excel together again.

Hamill and Toftoy personally went a long way toward making the transition from Germany to the United States work. As one participant in Operation Paperclip later wrote, "General Toftoy, Colonel Hamill and their staff did not act as bosses, but as leaders and friends."

Their work, meanwhile, kept the scientists busy. And it eventually attracted the attention of journalists. From October 1945 to May 1950 the team built and fired V-2s at White Sands, New Mexico. As the science editor of *Time* magazine wrote at the time in his book on the subject, "A rocket shoot at White Sands Proving Ground is more than interesting, more than beautiful, more than exciting. It is inspiring in a way that is equaled by few sights on earth."

Family Roots

In 1947, von Braun returned to Germany briefly to marry his 18-year-old cousin, Maria Louise von Quistorp. The wedding took place at Landshut, Bavaria, on March 1. Later that month the newlyweds returned to the United States, accompanied by von Braun's parents, whose estate in Silesia had been confiscated by the East German government.

The first of Maria and Wernher von Braun's children, Iris Careen, was born in 1948. Her sister, Margrit Cecile, would be born

four years later, in 1952, followed by a brother, Peter Constantine, born in 1960. Wernher von Braun, along with all the rest of the German scientists and engineers of the rocket team, was putting down roots in America.

Paperclip: Wise or Unwise?

On the other hand, many American citizens felt a real concern about bringing former enemies into the country to work on sensitive military projects and paying them a salary out of taxpayers' money. Many of these scientists had been members of the Nazi party; some, including von Braun, also had accepted commissions in Hitler's dreaded SS. At the time, some of these facts were glossed over, even in the top-secret FBI files; in fact, changes were made in their histories to reduce Americans' objections to their staying in the United States.

In 1980, journalist Linda Hunt compared documents she obtained through the Freedom of Information Act. According to her article, published in *The Bulletin of the Atomic Scientists* and presented in a television documentary, Hunt proved that the files had been altered. In von Braun's case, the original security evaluation written in 1947 read:

> *Based on available records, subject is not a war criminal. He was an SS officer but no information is available to indicate that he was an ardent Nazi. Subject is regarded as a potential security threat by the Military Governor, Office of Military Government for the U.S. A complete background investigation could not be obtained because subject was evacuated from the Russian Zone of Germany.*

With the documents that could have been used to do a more thorough evaluation out of reach, no further inquiry was planned. Von Braun's position as an SS officer could be explained away because Peenemünde had come under SS rule at the end of the war, although this background, if generally known, would have made many people uncomfortable. But the phrase "a potential security threat" could have damaged his chances for U.S. citizenship, and without achieving that critical step, the country could not put many

of von Braun's talents to use. The report was later altered, according to Hunt's evidence, to read:

> *Further investigation of Subject is not feasible due to the fact that his former place of residence is in the Russian Zone where U.S. investigations are not possible. No derogatory information is available on the subject individual except NSDAP records, which indicate that he was a member of the [Nazi] Party from 1 May 1937 and was also a Major in the SS, which appears to have been an honorary commission. The extent of his Party participation cannot be determined in this Theater. Like the majority of members, he may have been a mere opportunist. Subject has been in the United States more than two years and if, within this period, his conduct has been exemplary and he has committed no acts adverse to the interest of the United States, it is the opinion of the Military Governor . . . that he may not constitute a security threat to the United States.*

The doctored evaluation, as it turns out, was more accurate than the original. Without question, not only was von Braun not a security threat, but as an "opportunist" who wanted to build rockets, he was a pronounced asset to the government of the United States, which wanted them built.

In one case, the U.S. Justice Department did later take action. Arthur Rudolph was a key engineer in rocket engine design at Peenemünde and later—as program manager of the Saturn V rocket—became a central figure in the American space program. But during the war years in Germany, according to the justice Department, he had held a responsible position at Nordhausen, the inhumanely run concentration camp that provided prisoner-slave laborers for V-2 production at Mittelwerke. Prior to his time at Nordhausen and after it, Rudolph had worked at von Braun's side for most of 40 years, in Kummersdorf when they had shared bachelors' quarters and visions of space, in Peenemünde, at White Sands, and later, in Huntsville, Alabama. In 1983, Rudolph received word that he had to surrender his U.S. citizenship and leave the country or face charges of war crimes. Although he denied the charges, he left the United States for Germany at the age of 76.

As the years passed, von Braun grew weary of the constant surveillance and questioning about his "Nazi background," although he understood the reasons for it. In the 1950s, he once remarked to an acquaintance, "That's the only thing I don't like about America," as he motioned to an FBI agent who was following the car he was traveling in. "They follow me wherever I go."

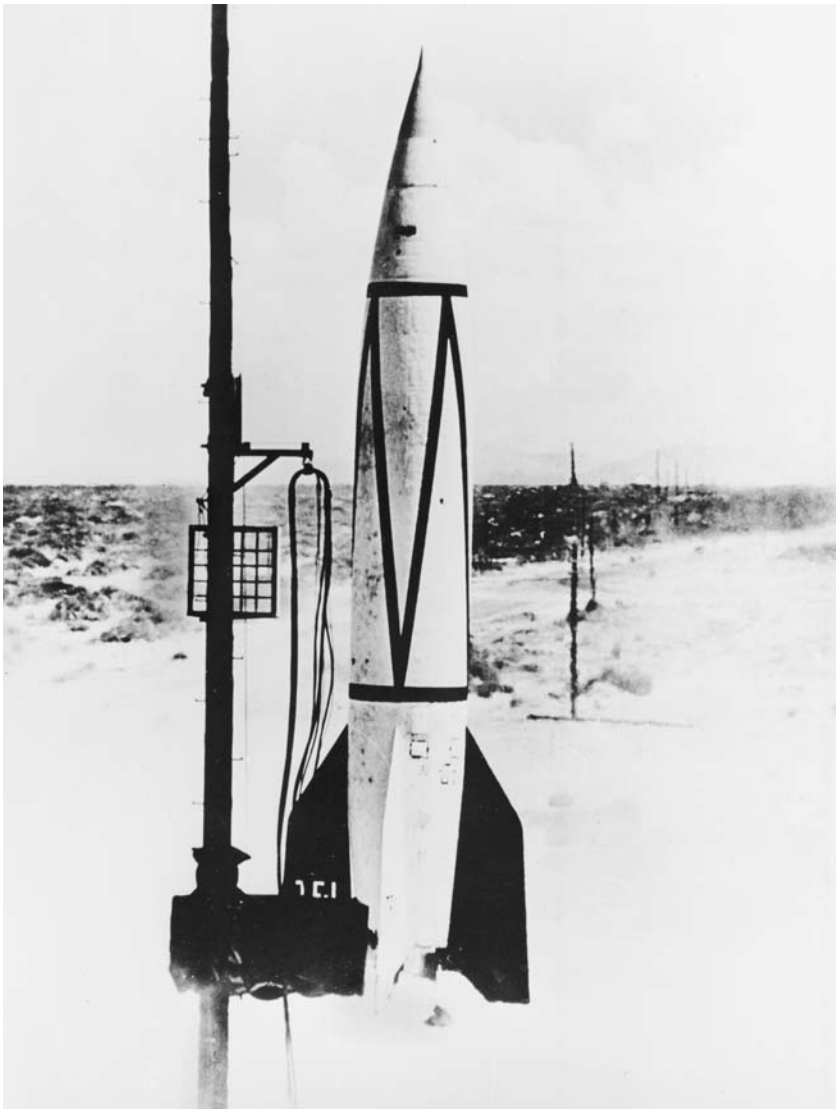
Building V-2s in White Sands

The original stated purpose of the German team's work was to train Americans, both civil and military, in the assembly, checkout, and launch of the large rockets they had designed. In the process, they would use the big V-2 rockets and their parts to gather data on the physical environment and radiation of the upper atmosphere.

On May 10, 1946, the first A-4 was launched to carry scientific instruments into the upper atmosphere. Several more followed that year, and, as always, the team had many failures as well as successes. The highest altitude attained by a U.S. A-4 was 132 miles (212 km). (By contrast, the experimental high-flying rocket plane known as the X-15 could fly only about half that high, and weather balloons reached altitudes only one-fourth that high.)

Demands for experimental space aboard the A-4s from government research agencies, the military, universities, and industry became so great that the A-4 Upper Atmosphere Research Panel was formed on January 16, 1947, to arbitrate requests and allocate space on flights. Between 1946 and 1951, the Hermes program, as it was known, launched 67 V-2s.

Another project developed during this period used specially adapted A-4s with modified nose cones. Called "Project Blossom" and sponsored by the U.S. Air Force Air Materiel Command and the Aero-Medical Laboratory, this program sent up canisters containing insect and plant life to study the effect of radiation on life forms at very high altitudes. Several rockets also carried mice and monkeys. In these earliest U.S. attempts to test the effects of ascent to extreme altitudes on living organisms, the nose cones were supposed to return to Earth via parachute. But the parachutes kept fouling and the ejection mechanism was not perfected, so the recovery method was poor, and few primate test animals survived.



A V-2 rocket launches at White Sands, New Mexico, in 1946. (NASA Marshall Space Flight Center)

In a project promoted by Toftoy, the team at White Sands also developed the Bumper missile, of which eight were launched between 1947 and 1950. The Bumper was a two-stage rocket—the A-4 was the first stage and a WAC-Corporal sounding rocket, weighing only 661.5 pounds (299.8 kg), was the second stage. These

rockets could go higher than the A-4 alone and could measure temperatures and cosmic radiation at much higher altitudes. Bumper No. 5, launched February 24, 1949, reached an altitude of 244 miles (392 km), a record at that time. It marked the first U.S. experience with large two-stage rockets.

Passports to the Future

In 1948, the U.S. government began dealing with a strange problem that had arisen with Operation Paperclip specialists. Because they had entered the country as wards of the army, they had no passports or visas. Although the original six months of their contract had long since expired, officially they had never entered the country. The State Department, reluctantly convinced that most of these men were not national security risks, agreed that they could begin proceedings toward citizenship. But citizenship could not be awarded until five years had passed following the date of legal entry. The State Department therefore came up with an ingenious plan. Interested specialists could take a streetcar trip from El Paso across the Mexican border to Ciudad Juárez, where they would visit the American embassy and obtain visas for entry to the United States. From there they would hop the streetcar again and return to El Paso. Port of embarkation: Ciudad Juárez. Port of debarkation: El Paso, Texas. Von Braun and his team had now officially arrived.

Despite their contributions, though, and increasing evidence that they might stay longer, by 1948 von Braun's team began to feel frustrated. They began to refer wryly to their presence in the United States as "Project Icebox," because they began to feel that their talents, especially as a team, had been kept on ice for three years, with no apparent hope of a thaw. They felt their work was moving too slowly and was underfinanced, and that the project was directed by an ill-defined policy. They were especially disappointed by the lack of team projects, the kind of work at which they had excelled at Peenemünde.

Then, one day in 1950, Wernher von Braun gathered his team together to make an announcement. The White Sands testing ground had grown too small. (A misguided V-2 that had nearly caused an international incident by landing across the border in a

cemetery in Ciudad Juárez had proved the point—even though the former German rocket team liked to joke that they were the only German detachment to attack Mexico from within their base in the United States.) The army had decided to establish a new testing site at Cape Canaveral, Florida, where rockets could be launched over the water, as they had in Peenemünde. Von Braun and his rocket team, he explained, were about to say good-bye to the American Southwest and head east, to a little town in northern Alabama. It was a town he thought they would like, and there they would continue their work in rocketry.

Few of the scientists knew at the time that they were about to enter into a love affair with Huntsville, Alabama, and with American culture—about to become truly part of the suburban life of the 1950s, complete with outdoor barbecues, patios, and swimming pools.

Wernher von Braun was also about to embark upon a new phase of his life, one in which he would become a well-known public figure, his name a household word, and his visions of space the talk of the news media. He was about to become America's "practical prophet of space."

9

Prophet of the Space Age

Wernher von Braun did not really set out to be a prophet or a public figure. He was above all a practical man who believed in getting things done the most efficient way possible. In an ideal world, this would have involved 100 percent secrecy for his work and all the money he needed, not unlike the way the result-oriented Communist government in the Soviet Union ran things in the 1950s. But von Braun understood that the price he paid for American freedom was American openness.

"When the Kremlin wants ballistic missiles," he once said wistfully, "it tells the scientist to meet the schedule and doesn't worry about public relations." But that was not the American way. "Here," he added, "we must have money and public support. Congressmen must believe in what we're doing, and they won't until the public

believes in us." So Wernher von Braun began to take the case for space to the public.

When the German rocket team packed up for the move from White Sands to Huntsville, von Braun was 38. Even seven years

In the United States, von Braun began to use his talents as a speaker to promote space as early as 1950—as he observed that public opinion and receptivity to the cause of space exploration could help the U.S. government see the V-2's potentials more broadly. (NASA Marshall Space Flight Center)

later, when he was in his mid-40s, he still looked boyish, still had a broad, winning grin, and, as one reporter put it, "sometimes lets out a Falstaffian boff that reverberates through the corridors a little like the explosive echoes from one of his mighty jupiters [rockets]." His enormous zest for life was catching, and he swept others—both those working with him and the public in general—up in his enthusiasm for his work. His early talent for languages came in handy now—although he always retained a Germanic staccato in his consonants, his English was loose, even slangy, always colloquial, and very American.

Wernher von Braun knew how to communicate and he did it well, using the well-honed skills—first developed in his days with the VfR in Germany and later at Peenemünde—to promote his lifelong dream of sending humans into space.

He wrote articles. He made speeches. He produced plans for future spaceships, timetables for planetary expeditions, and blueprints for a space-based shipyard where space rockets could be produced. His ideas were far-ranging and ambitious. But his credentials and the solid proof his rockets represented kept people from putting him in the crackpot category. The respect he won in the United States was enormous.

He began by finishing a book he had been working on for years, *The Mars Project,* in which he outlined his vision of planetary exploration and space travel. However, every one of the 18 U.S. publishers he submitted it to turned it down—they thought it was too fantastic and improbable. It was finally published first in Germany in 1952 and then republished by a university press in the United States in 1953.

Raising Public Interest: *Collier's* Magazine

From March 22, 1952, to April 30, 1954, *Collier's* magazine published a series of articles that predicted some aspects of the future with uncanny accuracy. The articles came out in eight installments, written by members of a panel of experts brought together to discuss space realistically and to offer a blueprint for space exploration. The

articles grew out of three symposiums on space sponsored by the American Museum-Hayden Planetarium in New York.

Collier's treated the articles as future science fact, not science fiction, and they were a conceptual tour de force. Von Braun's articles provided factual, detailed descriptions of spaceships and launch vehicles, based on work he had already done and was currently doing at the Redstone Arsenal in Huntsville. Chesley Bonestell, the highly talented space illustrator, provided many of the images for the articles. The impact was enormous, and the message that came across was, "All this is really possible, and not so very far off in the future."

Many obstacles to reaching space are purely imagined, von Braun liked to say. As he told one reporter:

> *A rocket propulsion expert will tell you there's no sweat in solving propulsion problems but the medical problem is the barrier. A doctor will tell you space flight is medically possible but he doesn't think propulsion can be licked. Many of these obstacles will fade away. Look at the sound barrier and the heat barrier.*

Intense, always enthusiastic, and popular, von Braun enjoyed signing autographs for a crowd of admirers. (NASA)

As the political importance of the space program grew, the establishment of the George C. Marshall Space Center was a natural step. Von Braun and his team were transferred from the army to Marshall (also in Huntsville) and von Braun became its first director in 1960, a position he would retain for the following decade. (NASA Marshall Space Flight Center)

His optimism was compelling, his wry sense of humor winning. "Right now," he added cannily, "we're up against the cash barrier, and that one doesn't always fade away so quickly."

Von Braun made as many as 50 speeches in one year when he was stumping for the army's missile program in the early years at Huntsville. He knew that getting the word out was an important part of the job and one of the keys to success.

Enter Walt Disney

But perhaps the most stunning result of all from the *Collier's* articles was the attention they gained from one of the great entertainment mavens of all time, Walt Disney. There are conflicting stories regarding who gave Disney one of von Braun's articles or even whether it was one written by him. But as a result of seeing the material, Disney

zeroed in on the subject of space as the theme for the Tomorrowland segment of his widely popular "Disneyland" TV show. He contacted Willy Ley (who had come to the United States in 1935) to design the segment and Ley put him in touch with von Braun, Ernst Stuhlinger, and Heinz Haber. Together they brainstormed their way to putting together a stunningly visual series of programs, complete with rocket models and von Braun's narration. Von Braun worked with the Disney artists to produce a fantastic drawing of a spoke-wheeled

I Aim at the Stars

In 1960, Wernher von Braun's life received the full movie treatment when Columbia Pictures released *I Aim at the Stars*, a supposed biography starring German actor Kurt Jurgens as von Braun. It may have been a signal that the movie industry was not sure how American moviegoers would react to the tone of the film that it was released in Finland a month before its American opening in New York City. Although the film made a modest amount of money during its initial release and can still occasionally be seen on television, film critics at the time were less than kind, in an assessment that seemed to reflect the opinions of many filmgoers. Bosley Crowther of the *New York Times* wrote "However one may think or feel emotional about the case of Dr. Wernher von Braun . . . one is not likely to have one's attitude changed by *I Aim at the Stars*. In the way of examination of the ethical reasoning by which the fabricator of the Nazis' deadliest missiles is now warmly accepted on our side, the film is conspicuously fuzzy and takes its stand on the not too certain ground that Dr. von Braun's driving intense interest from boyhood was simply to develop rockets that could reach out into space . . . the possibility of reaching intently into the depths of his scientist's mind and comprehending his certainly complex motivations is not achieved in this poorly written film."

An alternative title its producers considered for the film was simply *Wernher von Braun,* which, while less colorful, might have been a better choice. Shortly after the film's American release, a popular American television comedian suggested that the actual title should have been "I aim at the Stars, but sometimes I hit London." The joke continued in memory long after the film had been forgotten.

space platform, with human beings stepping off into gravity-free space and shuttle rockets coming and going. It was probably thanks to the public exposure on "Disneyland" that von Braun became the only nonastronaut associated with space whose name became a household word.

Von Braun soon became so widely known that he finally had to get an unlisted phone number at home—especially after a man called one New Year's Eve asking for a ticket to the Moon. By 1957 he would get about 10 letters a day on space and traveling to the Moon, about half of them from kids wanting to know how to pursue a career in rocketry—to which von Braun would reply, as his own teacher had, to study math and physics heavily.

To promote his cause, he used his full arsenal of humor and boyish charm. He also could use the ammunition of fear persuasively. In a 1952 speech he urged that the United States build a "manned satellite to curb Russia's military ambitions."

By the late 1950s Congress frequently consulted von Braun, who provided extensive testimony at hearings, in addition to his other speaking engagements and duties at Huntsville.

And then suddenly what still seemed to many people like space fantasy became space history: A beeping ball that signaled its presence from beyond the atmosphere to every nation on Earth was launched. This tiny, spinning ball of metal was lobbed into space by a giant military power on the other side of the world.

10 Huntsville Becomes Rocket City

On October 4, 1957, the Union of Soviet Socialist Republics (USSR) launched a 23-inch (58-cm) ball of polished metal weighing 184 pounds (83 kg) into orbit around Earth. The world would never be the same again. This little blinking ball was the first artificial satellite and, with its launch, the space age had begun.

Sputnik: The Space Race Is On

Beeping and flashing across the night sky where all could see it, this new object seemed at the same time magical and menacing. The Soviets called it *Sputnik,* and its presence became an extraordinary symbol of Soviet technical expertise and rocket power. Within a month they had launched *Sputnik 2,* this one weighing a whopping 1,120 pounds (508 kg) and carrying a dog aboard, again into Earth's

orbit. In the United States, the effect was galvanizing. With these launches, an intense, 12-year space race against the Soviets began, and Wernher von Braun's dream of sending humans into space was the ultimate goal.

But the Soviets' launch of *Sputnik* had not surprised the U.S. government as much as many Americans thought. And Wernher von Braun was probably the least surprised of all. Two years earlier, he had submitted plans to launch an American satellite based on the rocket technology already developed and tested at that time.

Waiting on the Back Burner

While von Braun had been writing articles for *Collier's,* entertaining interviewers from *Life, This Week,* and other magazines, and working with Walt Disney on futuristic views of space travel, the U.S. government had made a strange decision. In 1955, it had decided to limit von Braun's team, working for the army at the Redstone Arsenal, to developing intermediate-range missiles, leaving the longer-range intercontinental ballistic missiles (ICBMs) to the air force and the project of launching a space satellite to the navy.

The Redstone crew had been busy during the last seven years developing two sturdy rockets, the Redstone and the Jupiter missiles. Despite the limitations, von Braun and "The Team," as he called the rocket crew, had modified one of their Jupiter rockets by adding another rocket on top. This two-stage rocket had flown at least 3,600 miles (5,793 km) in a test and had reached an altitude of 600 miles (965 km)—higher than *Sputnik's* top altitude, although not fast enough to enter orbit. But it could have.

In much the same way that he once had contended with interference from the German SS, von Braun now had to contend with interference from U.S. political factions. In an interview with *Life* magazine in early November 1957, von Braun remarked:

> *We should declare a moratorium on obstructive inspections and monitoring by scientific committees and let the people building the Atlas, Titan, Thor, Jupiter and Polaris [rockets] work in peace. I just wish someone had the authority to tell me, "All right, we'll leave you alone for two years, but if you fail we're going to hang you."*

At Home in Alabama

Despite his complaints, the move von Braun and his colleagues had made to Huntsville was the best career opportunity of their lives. At first, though, it might not have seemed that way. Huntsville was a little cotton town in the South, its greatest claim to fame the champion milk-producing cow in America. When the army decided to revive the arsenal in the town, local residents weren't at all sure this was good news. Arsenals had come and gone before, and when they closed, the damage to the local economy was enormous. Little did its residents suspect that their town would soon become known as "Rocket City."

In 1950 Wernher and Maria von Braun and their two-year-old daughter, Iris Careen, had moved into a small house with a big, four-paneled picture window looking out on the neighborhood and the rolling Alabama countryside. By 1957 they were well settled.

"The Team" at Work

At work, as usual, von Braun was organized, efficient, and practical. In 1957, he still drove a weatherbeaten Chevrolet and carried his lunch of apples and pears, which he ate while catching up on his reading. Usually he was the first to arrive at the closely guarded building, passing rows of combination-locked, safelike office doors on the way to his third-floor corner office. His desk was stacked with piles of documents stamped TOP SECRET—scores of production reports and memos about technical disasters and breakthroughs.

Always a hands-on manager from his Kummersdorf days, his colleagues liked to say that von Braun was never satisfied until his hands "felt the touch" of each piece of a rocket's mechanism.

"I've never felt my job was to sit in my office and think," he once said.

> *Missile building is much like interior decorating. Once you decide to refurnish the living room you go shopping. But when you put it all together you may see in a flash it's a mistake—the draperies don't go with the slip covers. The same is true of missiles. Sometimes you can take one look and see something obviously wrong—not accessible perhaps, or too flimsy. The people who are working with it all day are too close to see it.*

> *That's why I go to the fabricating shop—I want to know what my baby will look like.*

He liked to gauge success by the "looks and feel of the hardware."

Without question, the October 7 launch of *Sputnik* had sent the country into a turmoil, and Wernher von Braun immediately turned up in the calm eye of the hurricane that followed. The United States, he assured the many reporters who asked, did not lack the genius required to compete in the arena of rocket technology. No country, he said, could hold a monopoly on technical intelligence. As he told *New York Times* reporter George Barrett in an October 1957 interview:

> *Take a group of people with the same general fund of knowledge, present them with a problem and you will get it done. The idea of a great genius sitting quietly in some corner dreaming up vast secrets is no longer real. So many things in modern science have become so wide in scope, so intricate, that more and more it takes groups of experts to do the work.*

The same laws of physics applied everywhere in the universe, he liked to point out. All that was required was rolling up one's sleeves and getting down to work—teamwork.

But in the flurry following *Sputnik*'s launch, President Eisenhower decided not to go with von Braun's Redstone rocket. Instead, he decided to stick with the untried rocket being developed by the navy, the Vanguard.

Frustrated, even angry, von Braun and General John Medaris, commander of the Redstone Arsenal, went immediately to Secretary of Defense Neil McElroy to plead their case.

"Vanguard will never make it," von Braun said. "We have the hardware on the shelf. For God's sake, turn us loose and let us do something. We can put up a satellite in sixty days, Mr. McElroy! Just give us a green light and sixty days!"

In later years von Braun tried to put a less parochial cast on the frantic opinions he expressed at the time. Vanguard is, in von Braun's later words, "one of the most sophisticated and one of the finest pieces of engineering I have known . . ." However, he added,

"Vanguard is a young racing horse, and one can expect it to be a bit capricious."

Vanguard's Day

It was, to say the least, capricious the day the navy invited TV cameras and press to watch the historic liftoff. Tension, of course, was high, as Kurt R. Stehling, head of the Vanguard Propulsion team, relates in his account of the launch:

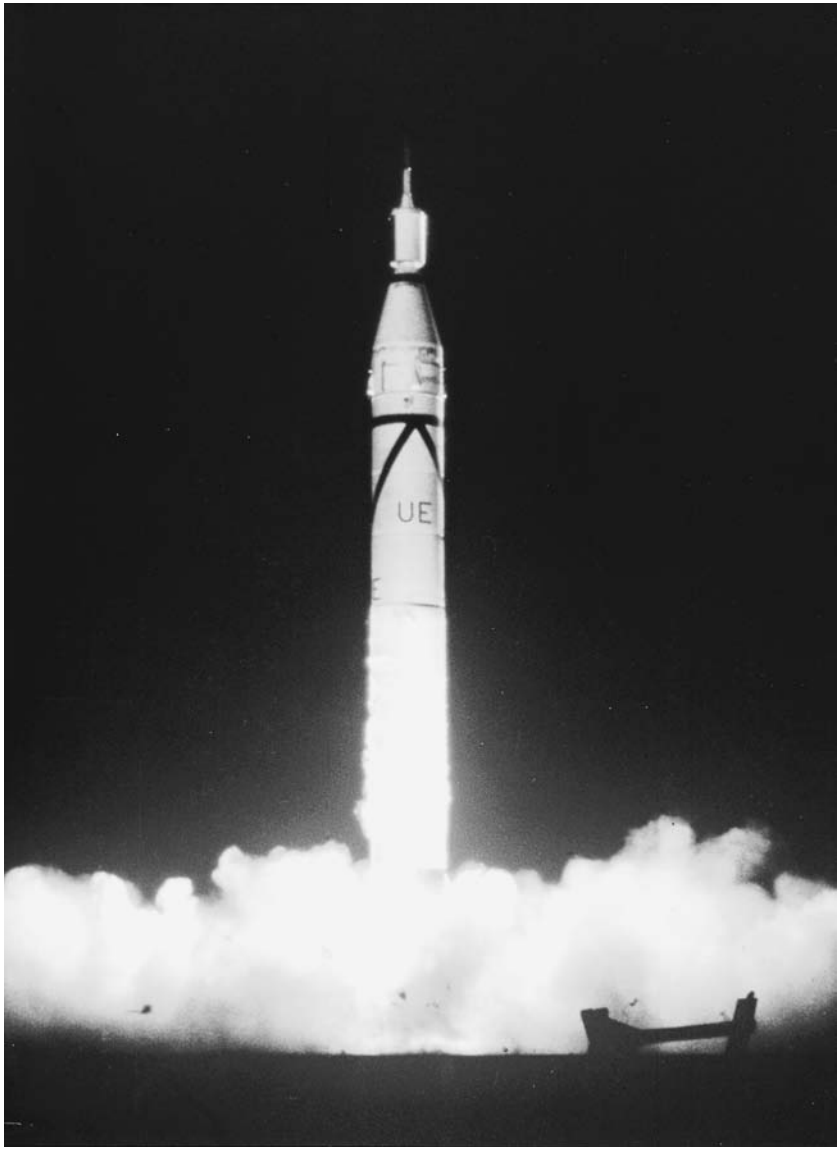
> *T-0 seconds. The final fire switch was closed. The last second-stage umbilical cord dropped. The rocket engine began to show sparks and fire as the pyrotechnic igniter in its inside ignited the beginning of the oxygen and kerosene fumes. The time was 11:44:559 A.M. America's first satellite was about to take off.*
>
> *The engine started with a heart-rending, hoarse, whining moan like that of some antediluvian beast in birth pain. Flame filled the nozzle, dispiritedly at first, and then built up with a great crescendo to a tremendous howl, brilliantly white, streaked with black. The vehicle shook itself momentarily like a wet dog. Ice and snow fell off the sides. The banshee howl of the engine increased. The vehicle hesitatingly ripped itself loose from its iron womb and rose slowly. We rose up with it on our tiptoes.*

At that moment, someone screamed, "Look out! Oh, God, no!"

Suddenly bright flames stabbed out from near the engine. The whole rocket seemed to pause, deathly still for a moment, and trembled. Then, as shocked observers looked on, instead of lifting powerfully off the launch pad, the big rocket began to topple, sinking downward into itself, breaking apart, colliding against the test stand, crashing to the ground. Even behind the protection of the two-foot concrete walls of the blockhouse and the six-inch-thick bulletproof glass, the deafening roar and the giant tremor jolted every observer. The launch pad area was flaming red with fire.

When finally the flames were doused, Stehling and his team could see out the windows into the steam and smoke. "The fire died down," Stehling would later write, "and we saw America's supposed

response to the Russian 200-pound *Sputnik* satellite—our 4-pound 'grapefruit'—lying amid the scattered glowing debris and, unbelievably, still beeping away, unharmed."



By January 1958, within weeks of the Navy's embarrassing Vanguard fiasco, a Jupiter-C (modified Redstone) rocket was ready to launch with its payload, the Explorer 1 *satellite, designed to make observations about Earth's upper atmosphere.* (NASA Marshall Space Flight Center)

Though the satellite, miraculously, had survived, the humiliation could not be overcome by anything but stoic courage. The moment of horror was over and could not be reversed. The navy team's attitude was, okay, time to clean up and get the next rocket ready.

The Team's Success

The next shot, however, would not go to the navy. Concerned about the humiliation caused by the very public Vanguard disaster, President Eisenhower gave von Braun and his team the nod.

Von Braun and his team leapt into action, and by January 31, 1958—not much over his promised 60 days—the Jupiter-C rocket put together at Redstone sent a small satellite named *Explorer 1* zooming into space.

Only 15 years had passed since that blustery October day in 1942 when von Braun and his rocket team had stood on the shores of the Baltic Sea to watch the first successful V-2 rocket fly into the clouds. Now they recaptured that exhilarating moment once again—only this time the goal was unquestionably space.

By March 3, 1959, von Braun's team also succeeded in launching the *Pioneer* probe. It was the first satellite to orbit the Sun successfully and the premier performer of an exciting series of spacecraft that would explore the planets, sending back images and data.

Von Braun's visions of space travel and planetary exploration were beginning to come true at last.

11

Sputnik and the Spotlight on Space

Despite the *Explorer* success, the embarrassment of *Sputnik* would not go away. For one thing, while the U.S. satellite had served a scientifically useful purpose—detecting radiation belts around Earth (sometimes called Van Allen belts) that no one had known existed—*Explorer* was still just a tiny grapefruit compared to the big *Sputnik*s. And everyone knew that it took massive power to put a heavy chunk of metal out into Earth orbit. The superior lift power of the Soviet Union's rockets translated into superior missile power if they were used as intercontinental missiles, aimed at another country instead of at the stars. Unlike the German Nazi government, which had wanted to squelch all talk of space, the Soviets were using space to tell the world about their military might. In the cold war rules of the day, the United States had to talk back.

The Next Move

Clearly the United States would have to meet the challenge, and the obvious next move was to put a human into space. Von Braun and his team submitted a proposal they called "Project Adam" shortly after *Explorer*'s launch in 1958. Its purpose was to send an astronaut into space. At about the same time, the National Advisory Commission for Aeronautics (NACA) proposed a similar project to put men into orbit around Earth. Both proposals were taken seriously.

None of this would have been considered even remotely by the United States in the 1950s, though, if the Soviet Union hadn't forced the issue. President Eisenhower had no interest in pursuing space exploration, but clearly he had no choice. In an effort to defuse the military impact of the Soviet Union's success, he reformed NACA in 1958 as the National Aeronautics and Space Administration (NASA), a civil agency that would be in charge of future space projects.

By the spring of 1959, a small group called the Space Task Group at Langley Research Center in Virginia had begun to talk about what would be involved in a manned lunar landing. It was the first time any of the group had really thought about it. Von Braun was there, from Huntsville, and Max Faget, a creative young Langley engineer. Maybe the astronauts should orbit the Moon, Faget suggested. Look down on it with binoculars as they flew by. Von Braun was impatient. They could just go in for a landing, he said. Already he had laid out in his mind the series of steps they would follow. An uncrewed robotic landing program called Surveyor was already planned.

"Max, you're completely overlooking all that we're going to learn in the Surveyor Program," von Braun said. By the time a manned landing was made, he surmised, the process would be old hat.

Going to the Moon

The first step in proceeding with any kind of manned space program was to test out the air force's Atlas rocket. On June 9, 1959, "Big Joe" lifted off from Cape Canaveral in Florida carrying a Mercury space capsule, the tiny little spacecraft that astronauts eventually would travel in. It reached a height of 160 miles (257 km), and then the Atlas spun around and sped back into the atmosphere at speeds up

to 17,000 MPH. From measuring devices attached to the capsule's titanium shingles, the scientists could find out how much heat this reentry would generate, and they could see how well the shingles held up. Similar test launches continued throughout the development of the manned space programs, revealing much about the various systems with each test.

Two months after the Big Joe launch, Eisenhower officially transferred Wernher von Braun (along with the rest of his team) to NASA, which had established the brand-new George C. Marshall Space Flight Center in Huntsville, right next door to the army's Redstone Arsenal.

Von Braun's strong point always was getting things done. He could bolt down great quantities of work in a single gulp. He could command a meeting of people in a way that generated dedication and enthusiasm, that led rather than brow-beat. Those who worked with him respected the wisdom of his experience and his ability to state his case coherently and cohesively.

"Von Braun," his former personal assistant, Dieter Huzel, once wrote, "didn't conduct a meeting, he led it with perception and incisiveness. He knew most problems at first hand, and those few that he didn't, he knew by instinct bred of long, intimate and successful experience in the field."

The Space Task Force at Langley would be responsible for developing the spacecraft, or capsule, while the Marshall team would develop the launch vehicle. (The Space Task Force moved to Houston, Texas, in 1961, where it became the Manned Spaceflight Center and later the Johnson Space Center.) In 1960 von Braun became the director at Marshall, a position he would hold for the next 10 years.

For the two groups, the immediate goal was to send a human astronaut into space. For von Braun and his rocket-building team, the challenge became to build rockets capable of lifting spacecraft and human cargo there. For them it was the dream come true at last.

The Mercury program, the first of several increasingly more complex programs, was begun in November 1958. It was designed to send one person at a time orbiting around Earth. All did not go well, however. An empty Mercury capsule was launched atop an Atlas launcher in July 1960 to test the capsule's ability to reenter the

atmosphere on a ballistic (free-fall) trajectory, but the rocket failed. A second test combining the Mercury capsule with the Redstone rocket also was unsuccessful due to rocket failure. No one wanted to send an astronaut into space without trying the effects of the journey on a test animal first. But the first test animal to go did not make the trip until January 31, 1961, when Ham the chimpanzee took the ride into space atop a Redstone rocket. Several things went wrong—errors during liftoff subjected him to an incredible 170 gs (17 times the effect of gravity), and the spacecraft leaked when it splashed into the ocean. But Ham seemed fine. (Ham lived to the age of 26 in a North Carolina zoo, where he died in 1983.) Ham's good health on his return to Earth encouraged the astronauts' confidence in the system.

The first manned flight—like Ham's flight, a suborbital lob from a Redstone launcher—would not take place until May. The delays had eaten up time.

Then the news came in. On the morning of April 12, 1961, the Soviet Union announced that Cosmonaut Yuri Gagarin had made an orbital flight of one hour and 48 minutes. Everyone knew the Soviets had been close to a launch, but the length of the flight was stunning.

Alan Shepard, the first U.S. astronaut to enter space, would not make the trip until May 5. His flight consisted of a 15-minute hop in the capsule he had named *Liberty Bell 7.* Unlike Gagarin, however, he did not ascend into Earth orbit.

Once again the Soviets were too far ahead to catch easily—the Atlas rocket was not ready yet and, originally, all seven Mercury astronauts were scheduled to make suborbital flights using the smaller Redstone launcher before trying to reach Earth orbit. Now that plan was scrapped. Only Shepard's flight in May and Gus Grissom's flight in July would be launched by the Redstone unit, and neither would reach orbit. Not until February 20, 1962, 11 months after Yuri Gagarin, would the first American complete an orbital flight in space: John Glenn aboard a Mercury capsule launched by an Atlas rocket.

In the same week as Gagarin's flight, President John F. Kennedy faced the low point of his administration—a group of Cuban patriots had stormed the Bay of Pigs in Cuba from the shores of Florida, with Kennedy's prior knowledge and approval. But when they were out-

The seven Mercury program astronauts (known as the "Mercury Seven") confer with von Braun (right). (NASA Marshall Space Flight Center)

matched by 20,000 Cuban troops, Kennedy could not risk escalating the conflict into a war with Cuba's ally, the Soviet Union. He had to leave them unsupported.

Now the Soviet Union had beaten him at the space game again. Clearly he would have to make a move. Kennedy saw that he could make one of three choices: Quit the race entirely, remain second to the Soviets, or make a commitment to beat them to the Moon. The first two were not good options.

After much deliberation on ways and means and what was possible—including consultations with von Braun and others—Kennedy made his decision. With Shepard's first space flight safely completed, on May 25, 1961, in a speech to a joint session of Congress, John F. Kennedy proposed that the United States should establish as a goal a manned mission to the Moon within the decade.

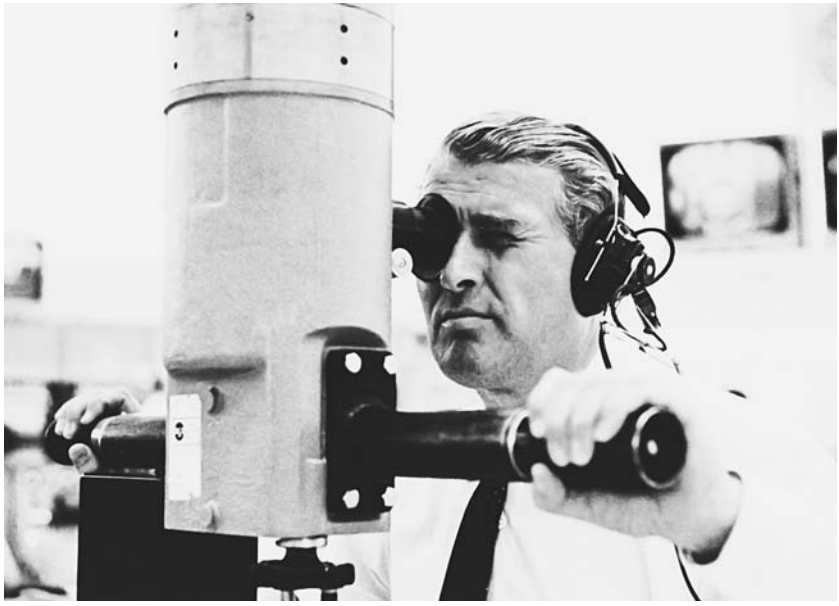
12

Success: *Saturn* Soars and the *Eagle* Lands

When President Kennedy announced the U.S. commitment to send a man to the Moon within 10 years, everyone knew it would take a committed, focused, all-out effort. At that time the United States did not have rockets powerful enough even to put a man into orbit, much less send him beyond Earth orbit, far out into space.

The Job: Design, Build, Test

That was von Braun's end of the job. On the surface it could be made to seem a puny task. All he had to create was a piece of machinery that could operate for under 18 minutes total: It would burn 6 million pounds of fuel in bursts lasting 2½ minutes and 6½ minutes, followed by 2-minute and 6-minute bursts. And that was it. But putting together a rocket that had the necessary power *and* control was no small matter.



Even as director of Marshall, von Braun liked to function in a hands-on mode—for example, using a periscope to check on rocket launches himself. (NASA Marshall Space Flight Center)

There were, of course, many other complexities—the design of the main spacecraft (known as the Command Module), decisions about the design of the Lunar Module (a secondary spacecraft to transport astronauts from the Command Module orbiting the Moon to the lunar surface and back to the Command Module), and endless details involving the safe transport of astronauts through the unforgiving, airless expanse of space. So much about what might happen out there was not known.

But if von Braun and his team did not do their jobs well, those astronauts might never even get off the ground.

The Apollo program would build on the lessons learned from Mercury and from a second program, Gemini, which sent two astronauts up together in a spacecraft. During the Gemini program, the astronauts completed many exercises that were necessary in planning a successful Moon landing, including docking with another spacecraft, extravehicular activities (EVAs), and transferring from one spacecraft to another.

For the rocket builders, plans for a Moon mission meant dovetailing their work developing rockets with that of other branches of the Apollo program. The biggest job, of course, would be sending a crew of astronauts, the Command Module and the Lunar Module to

Von Braun gives a briefing to President Dwight D. Eisenhower on the development of the Saturn rocket engine during a visit by the president to Marshall Space Flight Center. (NASA Marshall Space Flight Center)

the Moon. For this job, von Braun and his team immediately began designing the giant Saturn V rocket. They began with several smaller vehicles that could work either together, as the Saturn V, or separately, for less daunting tasks than the Moon landing.

On October 27, 1961, the first Saturn vehicle was launched, the Saturn I. It was 162 feet (49 m) tall and weighed 460 tons (417 m tons), "fully loaded" at liftoff. It traveled to an altitude of 85 miles (136 km) and made a nearly flawless run.

The work was going well, and by 1962 the von Braun family had moved from their first Huntsville house on McClung Street to a new, trilevel home on a narrow, winding street called Big Cove Road, located on a shady hillside known as Monte Sano.

Meanwhile, the Gemini flights continued, now using the early Saturn rockets. The design concept was functioning reliably—it was safe to move on to perfecting the Saturn V.

Saturn: Rocket Giant

From the beginning the design principle called for close analysis of test flight data. The guiding notion was the safety of the crew, and the team recognized early on that confidence in the rocket, especially considering its size and potential volatility, had to be based on the soundness of the engineering design. If a rocket flew perfectly three times, testing just to build confidence wasted resources and produced meaningless statistics. A rocket that has a three out of four success ratio still may blow up one time out of four. When you have people on board, those are not acceptable odds. The rocket had to work every time.

What the team created was an incomparable three-stage rocket, the Saturn V, a great, fiery furnace of a beast. It was as big and heavy as a navy destroyer ship, and it could deliver 7.5 million pounds (3.4 million kg) of thrust. What a long way these men had come since the days of the 660-pound (300-kg), 2,200-pound (1,000-kg), 3,300-pound (1,500-kg) engines at Kummersdorf! This giant was 281 feet (85.6 m) long and 33 feet (10.1 m) in diameter. The 82-foot (25-m) Apollo Command module was designed to sit on top, in the same

(Opposite page) *Apollo: Saturn V. The huge Saturn V is the largest rocket ever constructed by the United States.*

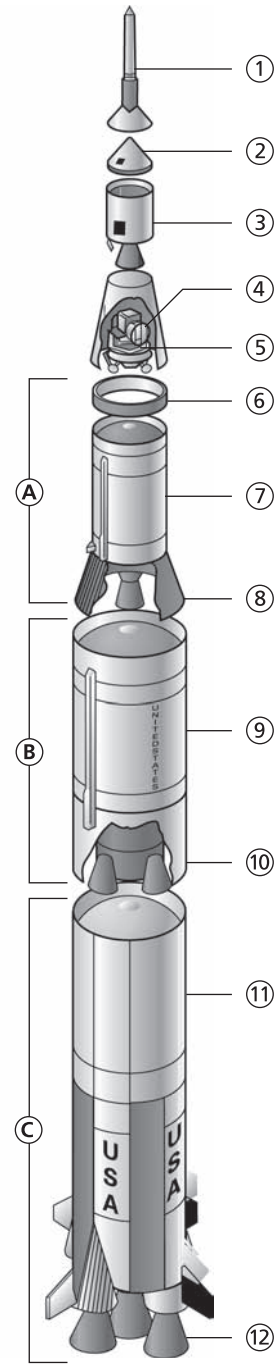
Apollo: Saturn V

Saturn V
1. Launch escape system
2. Apollo command module
3. Apollo service module
4. Apollo lunar module
5. Lunar roving vehicle
6. Flight control instrument unit
7. SIVB restartable third stage
8. SIVB J-2 engine
9. S-II second stage
10. Four J-2 engines
11. S-1C first stage
12. Five F-1 engines

A. Third stage
First burn to altitude of 118 miles (190 km); second burn insertion of Apollo into trans-lunar orbit

B. Second stage
6.5-minute burn to altitude of 115 miles (185 km)

C. First stage
2.5-minute burn to altitude of 38.5 miles (62 km)



Length
(with Apollo and escape system) 363 feet (110.6 m)
Weight
(fueled) 6,423,000 pounds (2,913,000 kg)
Thrust
(first stage) 7,650,000 pounds (3,470,000 kg)

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way the Explorer satellite had. From this position it would separate from the last of the three boosters, gaining sufficient speed to be thrust out of Earth orbit, streaking its way to the Moon.

The first Saturn V was launched November 9, 1967, from Launch Complex 39 at the Kennedy Space Center. The development was right on schedule, and the flight went without a hitch. Saturn V was ready to roll.

The first "live" Saturn V launch, with astronauts onboard, came almost a year later, when *Apollo 8* launched just before Christmas 1968. It was the third Saturn V to launch. In the Command Module were Commander Frank Borman, Command Module pilot James A. Lovell, Jr., and the Lunar Module pilot, William A. Anders.

This would be the first spacecraft to head out of Earth orbit toward the Moon. As the countdown completed, the big Saturn V booster produced its deafening roar and blinding flame. The big bird hovered for a moment and then slowly lifted. Within minutes the two spacecraft, still attached to the third-stage Saturn IV-B rocket, had achieved orbit around Earth. The astronauts orbited long enough to run a safety check on all systems, and then it was the job of the Saturn IV-B to power on and kick the Command Module-Lunar Module spacecraft into "translunar injection," sending it on its way to the Moon. This last stage of the rocket then dropped away, its duty completed and its fuel spent.

Almost miraculously, two days later the astronauts were broadcasting TV pictures and voices from an orbit around the Moon. They had made it!

Redundancy: Making Sure

In the long road leading up to the first Moon landing, two more test launches were scheduled. in February 1969 the *Apollo 9* crew went into Earth orbit to try out the docking and undocking of the Lunar Module close to home—so a rescue might be possible if anything went wrong. With so much combined experience, von Braun and the German rocket scientists knew how many things could go wrong in complex electronic and mechanical systems. Especially when human lives were aboard, they liked to play it safe. Redundancy—having a

backup system to take over if there is a problem with the primary system—was a key principle they instituted in the space program, and time and again their caution proved wise.

The rest of the Apollo engineers learned this lesson the hard way, back on January 27,1967, when the first Apollo crew climbed aboard the Command Module for a test-run simulation. Flawed wiring sparked the pure oxygen atmosphere in the module and engulfed the crew in flames almost instantly. Trapped inside, they all died.

The Command Module had suffered many problems with inferior parts and shoddy workmanship. Combined with insufficient safety precautions, these shortcomings had cost the lives of three men. The setback also was costly to the space program, and, like the explosion of the *Challenger* Shuttle spacecraft on January 28, 1986, the tragedy caused agonized rethinking on the part of everyone participating in the program.

The 1969 *Apollo 9* mission went smoothly, however, and on May 18 *Apollo 10* was rolled out on to the launch pad, ready for liftoff. This mission would test the Lunar Module in orbit around the Moon, without attempting a landing. The test went smoothly, leaving only one final challenge.

Going to the Moon: The Reality, *Apollo 11*

It was hot the morning of July 16, 1969, and the three astronauts—Neil Armstrong, Buzz Aldrin, and Michael Collins—lay on their backs inside the cramped Command Module as they waited for the countdown. Three miles away, in the launch control center, von Braun, launch operations director Kurt Debus, and the rest of the launch crew progressed point by point through the final countdown.

Liftoff. The blinding white exterior of the great Saturn V rocket shone like a beacon in the sunlight. Von Braun could see it out the window, poised on the launch pad, both mammoth and graceful, the apex of 45 years of work. The seconds ticked by. Everyone in the room felt the tension, the excitement, and the anxiety. At 9:32 A.M., a flame glowed beneath the huge engines, and slowly, slowly it rose up. The launch control center shook with the billowing shock wave

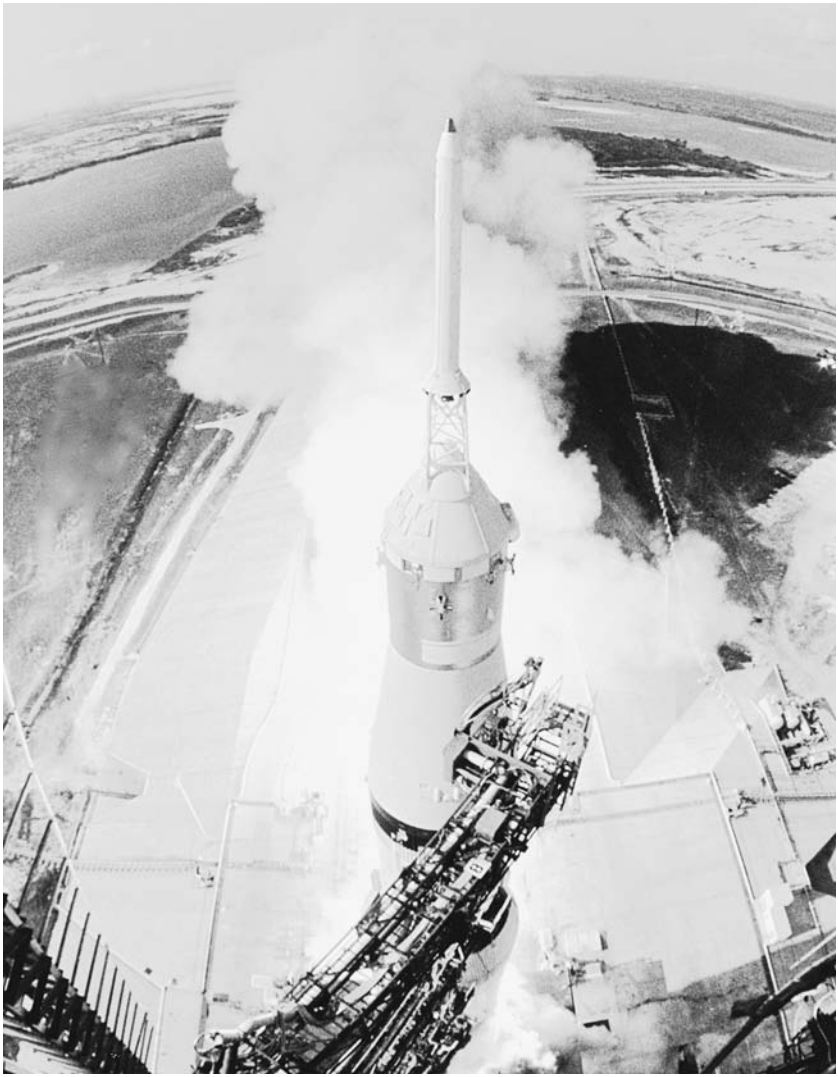
On July 16, 1969, NASA officials cheer with joy and relief as Apollo 11 *successfully completes countdown and liftoff.* (NASA)

from the rocket's roar. Now the rocket was lifting, pulling farther and faster away from Earth. Von Braun watched intently as it pulled upward, his eyes riveted to every contour, as if pushing the rocket upward with sheer willpower.

Then a noise jangled into his consciousness. The whole room had exploded with yells, laughter, and cries of joy—people shaking hands, clapping each other on the back. The mood of anxiety had suddenly burst into enormous relief and excitement. They had done it! Armstrong, Aldrin, and Collins were on their way to the Moon, and the rocket team had provided the first big push.

On July 20, Armstrong and Aldrin climbed into the Lunar Module named Eagle, undocked it from the Command Module in which Collins remained as pilot, and backed it away. In one of the most exciting adventures of all time, they piloted the Lunar Module down to within 50,000 feet (15,240 m), then burned the descent rocket to brake their movement toward the Moon to come in for a soft landing. Finally the message came over the intercom at Mission Control in

Houston, Texas. "Houston, Tranquility Base here," the voice crackled. "The Eagle has landed." Seven hours later Neil Armstrong stepped out on the surface of the Moon, the first human being ever to set foot on another celestial body. We had in fact flown out of our cocoon.



Apollo 11 *begins its long journey carrying three astronauts to the Moon, where two of them will land and walk on the surface of Earth's closest neighbor. Neil Armstrong and Buzz Aldrin become the first people ever to take this extraordinary step beyond Earth's cradle, while Michael Collins keeps watch from the command module.* (NASA)

Five more successful landings on the Moon followed over the next three years. By the late 1980s, Earth-orbit flights had become almost commonplace. And while interest in space waned after the early 1970s, space satellites, shuttles, and spacecraft have become a permanent part of our lives, interwoven with every aspect of our culture—a new culture that had begun in Germany years before, when a small boy sent for a book in the mail, a book whose equations and diagrams he trained himself to understand.

13 Next Stop, Mars?

Wernher von Braun left Huntsville, Alabama in February 1970 with mixed emotions. He was leaving the rocket team he had led for four decades. He was leaving a place that loved him, where people regarded him as a hero. In a lavish Huntsville farewell celebration, banners waved above the streets proclaiming: DR. WERNHER VON BRAUN—HUNTSVILLE'S FIRST CITIZEN—ON LOAN TO WASHINGTON.

Huntsville would never forget the bronzed, charismatic man with the sparkling eyes who had led the transformation of the sleepy little cow and cotton town into a booming center of rocket technology. Five years later the town dedicated a $14 million civic center named in von Braun's honor, with 2,000 people gathered for the ball thrown for the opening. There, Ernst Stuhlinger proposed a

toast, his champagne glass lifted high, and spoke for the city that had become his home. He said:

> *Twenty-five years ago, Wernher, when you and your coworkers lived in Texas, you told us one day that we would soon move to a place far in the East and deep in the South. You said the city of Huntsville had everything we could wish. There was plenty of room for our work, it was small, but a beautiful place to live, and all the people were extremely cordial.*
>
> *. . . we know that a man who is reaching for the stars cannot be held at one place on Earth for long, but we are proud that you made our city your home for twenty years. Those years certainly changed the face and the fate of the Earth . . .*

Washington, D.C.: A Cool Welcome

If, as his Huntsville friends proclaimed on that cold February day in 1970, von Braun initially left on loan from a place that loved him, he headed for a place that did not welcome him with open arms. His destination was Washington, D.C., where many people still regarded him with a mixture of envy and mistrust. And, of course, while he was, in essence, being promoted, he could expect to have far less influence and power as a deputy administrator at headquarters than he had enjoyed as director of one of NASA's centers. He would not, he knew, be groomed for the position of NASA administrator. While he had found a home and fame in America, he still carried with him the shadowy ghost of his past.

As Charles S. Sheldon, Ph.D., former White House staff member on the National Aeronautics and Space Council, would later remark: "There was always a lingering resentment at the Washington end toward von Braun and his team. There were always rumors that von Braun would someday be head of NASA. But there is a great sensitivity in Washington about racial and ethnic interests. . . . Von Braun would never be given a political position." Those who had not forgotten the Nazi extermination of millions of innocent people would not welcome a former member of the Nazi party into the seat of the U.S. Federal Government.

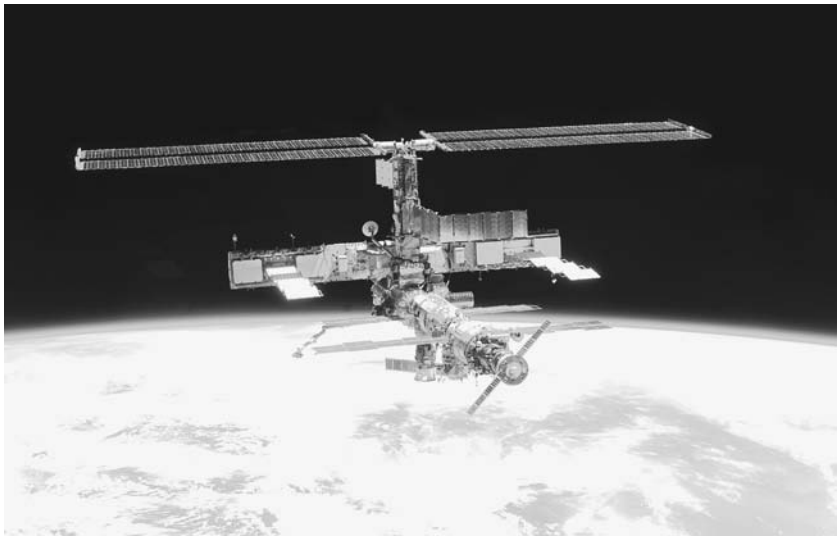
Voyage to Mars: Unfulfilled Vision

But finally NASA administrator Thomas O. Paine persuaded von Braun to accept the new post. Richard Nixon, then President of the United States, wanted to initiate a new space program—one to which his name could be attached, as Kennedy's had to the Apollo program, a new program of vision and scope. Even before Neil Armstrong and Buzz Aldrin had landed on the Moon, Nixon had formed a Space Task Group to project the next steps for NASA, and in September 1969 the group published a book called *The Post-Apollo Space Program: Directions for the Future.* About the same time NASA came out with *America's Next Decades in Space: A Report of the Space Task Group,* and a third publication, *The Next Decade in Space,* came out in March 1970 from the President's Science Advisory Committee. All three outlined an ambitious program aimed at a voyage to Mars by 1989. This was the kind of plan that von Braun could throw his energies into.

"Yes—we've walked on the Moon," he would say. "Now let's get the funds to go on to Mars."

They were ambitious and exciting plans, and they looked good on paper. But many, both inside and outside of NASA, had deep doubts that they would ever see fruition. While the more starry-eyed of the space enthusiasts felt their hearts quicken with hope, others, by the early 1970s, were beginning to feel that somehow a wonderful dream was over, that the optimistic magic of the '60s had given away to the cold economic reality of the '70s. For many dedicated space program watchers, the glowing optimism of the Space Task Force and NASA reports was numbingly depressing, so "unreal" in the light of political, social, and economic reality, that it made the achievements of the '60s seem almost equally unreal. Did the President of the United States actually set a public goal of landing a man on the Moon? Did an enthusiastic public applaud with enthusiasm and follow with baited breath each step along the way? Were wonderful rockets built and sent, and wonders returned? Or had it all been some science fiction magazine story, a dream that vanished too quickly upon awakening?

The world had changed, the Kennedy years gone, the peak of the space era over, and it had all seemed so quick, so brief after so many



Although the dream of an ongoing space program using both crewed and robotic missions seemed doomed in the 1970s, space exploration lives on. Wernher von Braun would be pleased to see the Russian and American teams of astronauts maintaining and continuing to build the International Space Station. Today this structure represents the difficult achievement of one of von Braun's great visions—a permanent human presence in space. (NASA)

years of waiting and dreaming. The "dreamers of the future" suddenly and ironically seemed like anachronistic relics of the past. These were not good days for von Braun. Usually able in the past to parlay his imagination, drive, practicality, and wit into viable, funded programs, now he seemed more and more like a useless spirit of another era. Where once he had been a symbol of what could be, now he seemed more a ghost of what once was—or worse, what almost was.

Paine: An Ally Lost

To make matters more difficult, on July 28, 1970, Thomas Paine resigned as NASA administrator to go to work for the General Electric Company.

Without Paine, who had spearheaded Nixon's Space Task Group, Nixon's flagging interest in space, drained by the growing political and economic problems facing his administration, waned even further. A new generation of NASA administrators greeted von Braun's efforts to breathe life into the mission to Mars with faint

enthusiasm. By the end of 1969 Nixon had announced that he would like to see a man on Mars by 1982, but his heart probably was never really in it.

In 1971—the year that von Braun had once enthusiastically predicted would see a permanent manned base on the Moon—as NASA

Von Braun visited India in 1975 to discuss educational uses of the ATS-6 communications satellite. Pictured here is the launch of ATS-6 on May 30, 1974, bringing educational TV programs to children in India. (NASA Kennedy Space Center)

prepared for difficult budget hearings in Congress, the former director of Marshall Space Flight Center, now 59, was often seen walking the halls alone. His charismatic boyishness and energy were missing, and he looked defeated and depressed as he emerged from planning sessions with the new administrator, James C. Fletcher.

On June 10, 1972, an era and a lifelong dream came to an end when Wernher von Braun retired from NASA to work for the first time in private industry—as vice president for engineering and development at Fairchild Industries, a major aerospace engineering company with headquarters in nearby Germantown, Maryland.

Final Days: Spirited to the Last

Fairchild had some forward-looking ideas, and the move fit well with von Braun's visionary style. Fairchild had built an Applications Technology Satellite, known as ATS-6, which the United States planned to lend to India for a year in 1975 for a massive educational project. TV transmissions from the satellite would be beamed to schools in some 5,000 Indian villages, making educational material available to youngsters who otherwise had no access to the world beyond their immediate communities. The government of India was in the middle of planning for an even bigger, long-range project of its own that could have a much more widespread effect—a system that could reach 500,000 such villages. It hoped to make five TV channels available, with materials offered in 25 languages, for its multicultural country. Fairchild, a leader in satellite technology and ground equipment, hoped to get the job.

The work required extensive traveling for von Braun, who, after years of speaking tours and NASA installation-hopping, thought nothing of making several trips in the space of days to locations as widespread as New Delhi, India, Tehran, Iran, and Washington, D.C.

He never ceased to stump for space, founding the National Space Institute (NSI; now the National Space Society) in 1974 to further the cause of space exploration.

In between consultations and speeches, he enjoyed his home in Alexandria, Virginia, where he and his family moved after leaving Huntsville. There he loved to swim in the pool and spend evenings in the luminous white observatory he had built in his backyard, spending

time with the Celestron telescope friends had given him on his 60th birthday. Wernher von Braun continued to function nonstop.

In July 1975, von Braun traveled to the Kennedy Space Center to witness the launch of the last Saturn 1B. Aboard, three astronauts—Frank Thomas Stafford, Vance Brand, and Deke Slayton—rode in an *Apollo* command capsule to meet and dock with a Soviet *Soyuz* spacecraft. In an unprecedented cooperative mission between the United States and the Soviet Union, Soviet cosmonauts Alexei Leonov and Valery Kubasov met in space with their American counterparts, orbiting together around the Earth in the historic *Apollo-Soyuz* "handshake in space."

Elated at the liftoff, von Braun confessed to CBS-TV news commentator Walter Cronkite, "I couldn't help but say 'Go, baby, go!' when ignition occurred." That same day von Braun rushed off to Stuttgart, Germany, to accept election to the board of directors of Daimler (Mercedes) Benz.

Then, in the midst of von Braun's energetic work with Fairchild and the NSI, he learned that he had cancer. Surgery failed to stem the progress of the disease, and ill health forced him to retire on December 31, 1976. President Gerald R. Ford awarded him the National Medal of Science just before he left office in early 1977, and it was presented to him in the hospital by Edward G. Uhl, chairman of Fairchild Industries. Tears came to the eyes of the man who, by his own description, came to this country with all his belongings in one pasteboard carton. It was a fitting final tribute from a nation who had made use of the considerable talents of a man who had become, in one lifetime, both a despised perpetrator of war and arguably the greatest proponent of space exploration.

As Harry Stine wrote in his book *ICBM:*

> *Personally, Wernher von Braun was not only a consummate diplomat but also one of the best engineers I've ever known. He was a role model. A man with dreams* and *academic credentials, a person who could theorize* and *design, an individual whose charisma was so powerful that he could instantly dominate any assemblage of people by his mere presence* and *who was also warm and friendly, he was also a practical person who knew how to work with his hands.*

Wernher von Braun died on June 16, 1977, in Alexandria, Virginia. He was 65 years old.

It was a day, unquestionably, for remembering his considerable contributions to the expansion of human knowledge and experience. In the words of President Jimmy Carter, "To millions of Americans, Wernher von Braun's name was inextricably linked to our exploration of space and to the creative application of technology. . . . Not just the people of our nation, but all the people of the world have profited from his work."

14

Wernher von Braun's Gift

Wernher von Braun never failed to be elated whenever he saw one of his huge "birds" soar upward from the Earth's crust toward what his colleagues came to call "von Braun's beloved stars." To him a rocket was a work of wonder, not one man's work but the result of consummate, tireless teamwork and a dedication to excellence, characterized, as he once wrote, "by enthusiasm, professionalism, skill, imagination, a sense of perfectionism, and dedication to rocketry and space exploration."

But thundering rockets are only a portion of the legacy Wernher von Braun left. The United States depended heavily on von Braun's know-how, vision, and leadership during the intense Apollo Project years, and even after his days at NASA, the space rockets that he had made possible continued to affect our lives—both in their military potential and in their scientific and commercial applications.

He had opened up the "space age" and, in so doing, precipitated, for a while at least, one of the most exciting periods in the history of human knowledge. Driven by national pride and military expediency, both the United States and the Soviet Union pushed heavily toward the exploration and use of space in the 1950s, '60s, and '70s. Every move that the United States made led to a move by the Soviet Union, and vice versa, each country always striving to get ahead or stay ahead in the "space race."

Between 1958 and 1976 the Soviet Union and the United States sent 80 missions—mostly unmanned—to the Moon. Both countries obtained vast amounts of new information, including the first photographs of the Moon's far side (which is always turned away from Earth). Probes to Venus, Mars, Mercury, and the far-flung outer planets soon followed both from Cape Canaveral (called Cape Kennedy 1963–73) and the Soviets' Baikonur launch site in Kazakhstan. The U.S. Pioneer and Voyager series were among the most stellar. As these roaming robots snapped images and sent signals earthward, they collected data that revolutionized human understanding of the Solar System and the Universe beyond.

By 1971, the Soviet Union had begun a marathon of experiments on living in space. Soviet "cosmonauts" spent ever-longer stays—up to a year or more—in a series of space stations culminating in the big Mir ("peace") station, launched in 1986. The United States, meanwhile, sent three teams of astronauts in 1973–74 to a space station called Skylab to study the Sun. Skylab itself was launched by a Saturn V rocket, and Apollo technology was used to launch the astronauts as well.

A Saturn rocket was also used to launch three United States astronauts into orbit aboard an Apollo Command Module, which on July 18, 1975, completed the historic docking maneuver with a Soyuz spacecraft piloted by two Soviet cosmonauts.

Then, in 1982, the United States launched the first of a fleet of Earth-orbiting vehicles called Space Shuttles or, officially, the Space Transportation System. Already a victim of waning congressional interest in the 1970s, however, the shuttle design was patched together after numerous budget cutbacks and was a far cry from the advanced designs envisioned by von Braun. Badly compromised in its design and mission, the U.S. Space Shuttle finally flew, making

This photo of Earthrise, taken from the surface of the Moon, supplied an entirely new perspective to the human inhabitants of Earth—an emerging view of the fragility of life and our biosphere. (NASA Glenn Research Center)

its first operational flight in November 1982. And, with the exception of a 2½-year hiatus following the tragic explosion in 1986 of the *Challenger,* the shuttle has proved a trusty vehicle for short-term scientific experiments in space, as well as complicated satellite launchings and repairs, often done by astronauts floating in the great expanse of the Universe with nothing more than a spacesuit between them and the vast vacuum of space.

In addition to deployment of countless satellites having a variety of purposes ranging from the scientific to the commercial, the space programs of both the United States and the Soviet Union have collected extensive data about the effects of weightlessness on living organisms (including humans), crystal formation, and countless other areas of inquiry. By the 1980s, many other countries, including China, Japan, India, and a consortium of European nations, had obtained the capability to launch satellites and had developed space programs of their own.

The current vast communications web—from complex television networks and "superstations" to the "Information Superhighway," from sophisticated weather reporting to "instant" news and communications transfers—could not exist without the satellite links that have truly made the world a global community. The great Saturn V rocket, one of which remains on display in Huntsville, continues to remind us of the enormous achievements reached by a team of engineers led by a man who held and communicated a great vision for the positive and creative potential of humankind.

All this was, in a way, positive fallout from the cold war between the United States and the Soviet Union. What to Tsiolkovsky, Goddard, Oberth, and von Braun seemed inevitable might never have happened when it did if two countries had not been vying to one-up each other in the eyes of the world. But as the cold war drew toward an end in 1989, and with the breakup of the Soviet Union in 1991, some of the spur for this surge of interest in the use and exploration of space dissipated. With both the United States and Russia facing serious financial and social problems, both nations began to cut back on their space programs. Among the first casualties, the Mir space station limped along, neglected, in the early 1990s, and the U.S. Congress reduced funds for a planned international space station called Freedom.

Visionaries in both nations, though, still plan and dream. Plans for a joint manned mission to Mars using both Russian and American technology have been brewing for years—and von Braun, one of the first to envision such a voyage, would have been elated at the prospect. With friendlier relations between the nations, the project is possible, but without a public mandate, funding may be scarce.

Conclusion:

Weighing Human Tragedy

Wernher von Braun left us with proof of human capabilities—a gift of powers never before explored and a model of care and concern. Yet he also left another presence, one of a man whose vision of possibilities and opportunities at times obscured other, more human values, values of integrity and conscience.

Twenty-five years after the end of World War II, von Braun wrote the following:

> *What is a man's duty who loves his native country, sees that it has fallen into evil hands, but also that its very survival is at stake? It is easy to answer this question from the safe shelter of a strong, well-governed nation, which is more or less at peace with the rest of the world. The answer does not come as readily when you live right in the midst of such a storm of events.*

But he should, perhaps, have asked two other questions: "How do we balance our obligations as human beings against our duties to our government or country?" and "When do we have an obligation to say 'No' and act against crimes we see committed around us?"

Did von Braun fall short during his years at Peenemünde in Nazi Germany? Could he have acted differently, or should he have? In his own words:

> *I have come to the conclusion that it is better for a man to respect another man's conscience than to sit in glib judgment of him. The final judgment on matters like this is surely in better hands with the good Lord. I thought, and I still do, that under the circumstances, I did what was my duty.*

One finds oneself asking the following questions: "How can one have a duty to one's country that is stronger than one's commitments to humanitarian principles? How could it be all right, for no reason other than example, for soldiers or police to shoot civilians point-blank so they drop directly into a mass grave? How could the sheer brutality of these actions be anything but insufferable? How could slave labor be okay? How can one excuse bombing civilians in an unwarranted war started by one's country? How could one stay and go on building rockets?"

Searching for fairness, one may also ask: "What about the Americans building the atomic bomb and dropping it on civilians in two major Japanese cities?" It is a fair and honest question, but consider the fact that the United States did not even enter the war until forced to by the Japanese attack on Pearl Harbor. Even so, J. Robert Oppenheimer, the scientist who directed the American development of the bomb, experienced and expressed extreme remorse for the thousands who were killed or maimed as a result of his work.

In counterpoint one asks: "Whom did Oppenheimer's postwar remorse actually serve?" Von Braun's postwar career enriched the world with astronomical discoveries, a changed human perspective, a positive and enormous legacy.

Whether, in the end, the question of conscience that outshines all other questions about Wernher von Braun is open to debate. His life raises the issue and thereby leaves a second, darker legacy.

During his last 30 years, he captured the Moon, the stars, Jupiter, and a skyful of planets—a stellar gift. His earlier years also provoked thought, forcing a consideration of the complexity of human ethical decisions and their consequences.

This two-pronged heritage—offering wide-open possibilities and posing deep-seated questions—epitomizes Wernher von Braun's mark upon our time.

CHRONOLOGY

1912	Wernher von Braun is born on March 23 in Wirsitz, a small town in Germany (now Wyrzysk, Poland).
1927	*Verein für Raumschiffahrt* (or Society for Space Travel) VfR is founded.
1929	Première of director Fritz Lang's acclaimed movie *Frau im Mond* (Woman in the Moon) about taking a trip to the Moon.
1929–30	Meets and gets to know Willie Ley, an influential member of the VfR
1930–32	Von Braun studies at institutes of technology in Berlin and Zurich. Meets Hermann Oberth and works with him on early experiments in liquid-fuel rockets.
1932	Von Braun earns B.S. in mechanical engineering at the University of Berlin. Becomes civilian employee of German Ordnance Department, continuing research into liquid-fuel rockets
1932–34	Continues his studies at the graduate school of the University of Berlin Sponsored by the German Ordnance Department, von Braun begins work at a small development station at Kummersdorf, which grows over time to a team of about 80 people.

1934	Earns Ph.D. in physics at the University of Berlin In December, the team is successful in launching two A-2 liquid-fuel rockets that reach altitudes of 1.6 miles (2.6 km).
1936–38	Works on development of rocket-propelled aircraft and liquid-fuel rockets, the A-3 and the A-4
1937	Activities at Kummersdorf are moved to the Liquid Fuel Rocket and Guided Missile Center that has been newly constructed at Peenemünde (employing more than 10,000 people at the height of its activity).
1937–45	Von Braun serves as Technical Director of Peenemünde until the war ends.
1938	Under orders, von Braun becomes a member of the Nazi Party.
1939	Germany invades Poland, an action that results in the outbreak of World War II, with England and France declaring war when Germany refuses to pull back. Germany continues its aggressive attacks drawing most of Europe into the battle, and Italy, Japan, Hungary, Romania, and Bulgaria join with Germany to form a coalition known as "The Axis."
1939–40	Von Braun successfully conducts nearly two dozen launches of A-5 rockets. They reach 10 miles (16 km) altitude and a range of 12 miles (19.3 km).
1941	On December 7, Germany's ally Japan attacks the U.S. Navy base at Pearl Harbor, Hawaii. The United States enters the war, joining the Allies (or Allied Forces), that include Britain, France, the USSR (now Russia and neighboring nations), Australia, and Belgium.
1940–43	In October 1942, the German rocket team conducts the first successful launching of a V-2 rocket.

1943	Von Braun works on the development of an anti-aircraft guided missile; successfully launching 44 rockets.
1944	Germany attacks London with V-2 rockets; more than 3,000 V-2 rockets are fired at the city; killing more than some 2,700 civilians in London.
1945	World War II ends with the surrenders of Germany and Japan. Von Braun and more than 100 other scientists surrender to the Allied powers. In June and July, von Braun is interrogated at the U.S Army interrogation camp in Bavaria. In September, von Braun arrives in the United States.
1945–50	Von Braun serves as project director, Research and Development Service, Sub-Office Rockets, U.S. Army Ordnance Corps, at Fort Bliss, Texas, also working as adviser for V-2 test launchings at the White Sands Proving Ground in New Mexico.
1950	Von Braun and the German team of scientists are transferred to Redstone Arsenal in Alabama.
1955	Von Braun becomes a U.S. citizen.
1957–58	Von Braun and his team develop and launch the first U.S. satellite, *Explorer 1,* transported beyond Earth's radiation belts (now known as the Van Allen Belts) by a Redstone rocket based on V-2 design. Von Braun becomes a leading advocate for the exploration of space, writing articles for newspapers and magazines and keeping up a steady list of speaking tours, continuing to be the most vocal U.S. space visionary throughout the 1960s.
1961	On May 25, President John F. Kennedy announces to a joint session of Congress and to people worldwide

	an ambitious plan to put an American on the Moon by 1970.
1960s	Transferred to the Marshall Space Flight Center and named director, von Braun works with other scientists and engineers in developing the Saturn V rocket, the vehicle that will carry American astronauts to the Moon.
1969	On July 20, two American astronauts, Neil Armstrong and Buzz Aldrin, become the first humans to stand on the Moon. A third astronaut, Michael Collins, remains in charge of the mission's command module as it orbits the Moon.
1970–72	Serves as Deputy Associate Administrator at NASA Headquarters
1972	*Apollo 17* becomes the last of the Apollo missions to the Moon; between 1969 and 1972 six successful landings are made on the Moon in the successful Apollo program. Von Braun leaves NASA for the private sector to become vice-president, engineering and development, for Fairchild Industries.
1977	Von Braun retires in January, fighting cancer, and dies June 16 in Alexandria, Virginia, at the age of 65.

GLOSSARY

A-4 the most advanced rocket developed to completion by the rocket team at Peenemünde; also known as the V-2

Apollo program the third and final set of astronaut-spacecraft programs that culminated (after testing in Earth- and Moon-orbit) in six Moon landings by astronaut crews; crewed spacecraft that traveled to the Moon included a detachable command module carrying a crew of three astronauts, a service module, and a Moon lander; all missions that traveled to the Moon and back were launched by giant Saturn V multistage rockets designed and built by von Braun's team (two preceding programs were Mercury and Gemini)

ballistic missile a projectile that falls in a free-falling flight pattern after a guided, self-powered ascent

ballistic trajectory the curved path of a projectile, such as a missile or a bullet in free fall, after the thrust or propelling force has ended

booster in a multistage rocket, the rocket that provides an early stage of propulsion, including the initial stage that provides power for the launching and first part of the flight

cold war after World War II, an extended period of animosity between the Soviet Union and the United States, when the countries were hostile to and uncooperative with each other, even though not formally at war

combustion rapid oxidation or burning

Gemini program the second in a series of three astronaut-spacecraft programs that served to prepare astronauts and develop spacecraft for travel to and from the Moon; each Gemini mission carried two astronauts (*gemini* is Latin for "twins"), who tested the first walk in space, spacecraft docking, and so on, in Earth orbit (the other two of these programs were Mercury and Apollo)

gyroscope a device usually consisting of a spinning mass (e.g., a disk or wheel), suspended so that it maintains the same orientation no matter which way it is turned, as long as it is not subjected to external

changes in velocity; can be used to automatically keep a craft in the proper relative position or at the proper attitude

launch vehicle another term for rocket

Luftwaffe German air force during the Nazi regime

Mercury program the first (1961–63) in a series of three astronaut-spacecraft programs that served to prepare astronauts and develop spacecraft features that would be needed later for travel to and from the Moon; astronauts flying these first U.S. flights flew solo in command modules designed to carry one person into space (the other two of these programs were Gemini and Apollo)

missile usually a rocket carrying a warhead, or bomb, as a payload

Nazi (National Socialist German Workers' Party) political party established in 1920, often called Nazi party, which peaked with Adolf Hitler's rise to power in 1933 and his establishment of the totalitarian government known as the Third Reich, which lasted from 1933 to 1945; imposed strict laws, anti-Semitic persecution, and severe limits on opposition and freedom, the racist Nazi regime was responsible for the imprisonment in concentration camps and tragic genocide of millions of non-Aryan men, women, and children, especially Jews

ordnance all supplies pertaining to weapons and their maintenance, including the weapons themselves

payload anything transported by a rocket or spacecraft that is not involved in its primary functions

projectile any object propelled forward by a force, for example, a bullet or a rocket

propulsion a force that propels, or pushes, an object forward

rocket a device propelled by ejection of matter, especially by the ejection of gases resulting from combustion

rocket engine an engine that produces propulsion, by ejection of matter, especially by the ejection of gases resulting from combustion; the motor portion of a rocket

sounding rocket a rocket used to obtain information about the atmosphere

SS (*Schutzstaffel* from German, "defense squadron") police organization founded by Adolf Hitler in 1925 for his personal protection, the SS acquired extended duties, including responsibility for administration of concentration camps during World War II

static test (or static firing) a test in which the rocket motor is fired, but kept stationary and not allowed to leave the test stand, provid-

ing an opportunity to measure engine thrust and other performance characteristics

upper stage in a multistage rocket, a booster rocket that take over after the first-stage booster has burned its fuel

V-2 Hitler's "Vengeance Weapon #2," originally known as the A-4 rocket

Wehrmacht German army, especially during the Nazi regime

FURTHER RESOURCES

Books Written by Wernher von Braun

Ley, Willy, and Wernher von Braun. *The Exploration of Mars.* New York: Viking Press, 1956.

Dated but interesting look at how scientists viewed Mars early in the Space Age.

von Braun, Wernher. *First Men to the Moon.* New York: Holt, Rinehart and Winston, 1960.

Von Braun revised and expanded his series of articles for This Week Magazine *in this fine-tuned book.*

———, *The Mars Project* (translation of *Das Marsprojekt,* Frankfurt am Main, 1952). Urbana: University of Illinois Press, 1953, 1962, and 1991.

Technical but readable arguments for getting humans to Mars.

———, Silvio A. Bedina, and Fred L. Whipple. *Moon: Man's Greatest Adventure.* New York: Harry N. Abrams, 1973.

One of the very best books on space exploration, with wonderful illustrations.

———, and Frederick I. Ordway III. *The Rockets' Red Glare: An Illustrated History of Rocketry Through the Ages.* New York: Doubleday/Anchor Press, 1976.

Nicely done history of rocketry.

———, Fred Whipple, and Willy Ley. *Conquest of the Moon,* ed. Cornelius Ryan. New York: Viking Press, 1953.

Based on the colorful and inspiring series of articles originally published by Collier's.

Books and Articles about Wernher von Braun

Bergaust, Erik. *Reaching for the Stars.* New York: Doubleday, 1960.

One of the earliest biographies of von Braun and still quite interesting.

———, *Wernher von Braun.* Washington, D.C.: National Space Institute, 1976.

Bergaust glamorizes von Braun, but this biography is gracefully and enthusiastically written.

Lampton, Christopher. *Wernher von Braun.* New York: Franklin Watts, 1988.

Laudatory biography, but lets von Braun off the hook concerning his V-2 days.

Neufeld, Michael J. *Von Braun: Dreamer of Space, Engineer of War.* New York: A. Knopf, 2007.

Takes a longer view than most contemporary biographies and asks probing questions about von Braun's ethics, meanwhile going light on von Braun's technological advances.

Piszkiewicz, Dennis. *Wernher von Braun: The Man Who Sold the Moon.* Westport, Conn.: Praeger Publishers, 1998.

While Piszkiewicz sees the grandeur of von Braun's vision and the greatness of his work, the author holds von Braun responsible for considerable involvement in German war crimes.

Stuhlinger, Ernst, with Frederick I. Ordway III. *Wernher von Braun, Crusader for Space: A Biographical Memoir.* Malabar, Fla.: Krieger Publishing Co., 1994.

A good look at von Braun by men who knew him and worked with him.

Ward, Bob. Dr. *Space: The Life of Wernher von Braun,* with a foreword by John Glenn. Annapolis, Md.: Naval Institute Press, 2005.

Written by a veteran space writer and former editor of "Rocket City's" Huntsville Times*, this recent look at von Braun's life captures a constant sense of the rocket builder's drive, intensity, creativity, and brilliance as well as his human side and keen sense of humor.*

Books and Articles about Rocket Development and Space

Of the many fine books on rockets and space exploration, we list just a few of the classics and a few of the most recent and insightful. In addition to We Seven*, many astronauts have written their own accounts of their space experiences.*

Baker, David. *The Rocket.* New York: Crown Publishers, 1978.

Good authoritative look at rocket history.

Burrows, William E. *Exploring Space: Voyages in the Solar System and Beyond.* New York: Random House, 1990.

Well done but now a little dated.

Carpenter, M. Scott, et al. *We Seven.* New York: Simon & Schuster, 1962.

The story of the first Mercury Seven *astronauts.*

Dornberger, Walter. *V-2.* New York: Viking Press, 1954.

Good technical information on the V-2, but embarrassingly self-serving.

Goddard, Robert H. *A Method of Reaching Extreme Altitudes.* Washington, D.C.: Smithsonian Institution, 1919.

For historians or the general reader.

Gray, Mike. *Angle of Attack: Harrison Storms and the Race to the Moon.* New York: W. W. Norton and Company, 1992.

Well-written and exciting story of the struggle to put humans on the Moon.

Hickam, Homer H., Jr. *Rocket Boys: A Memoir.* New York: Delacorte Press. 1998.

Hickam bases this novel on his own experience as a kid fascinated by rockets but living in a coal-mining town that offers few opportunities to fulfill his dream. It is the story of a child with a passion for rockets, who finds his place as an engineer, as Hickam did in real life in Huntsville, Alabama, the same place that was home a generation earlier for Wernher von Braun and his rocket team.

Holder, William G. *Saturn V: The Moon Rocket.* New York: Julian Messner, 1969.

Straightforward look at the Saturn V rocket, the space vehicle that made history.

Lehman, Milton. *This High Man: The Life of Robert H. Goddard,* with a preface by Charles A. Lindbergh. New York: Farrar, Straus and Co., 1963.

Fine look at rocket pioneer Robert Goddard.

Ley, Willy. *Rockets, Missiles, and Men in Space.* New York: Viking Press, 1968.

Like all Ley's books, this is an engaging, well-told tale.

Manno, Jack. *Arming the Heavens.* New York: Dodd, Mead and Company, 1984.

Manno looks at the space race and the military agenda.

McDougall, Walter A. . . . *the Heavens and the Earth.* New York: Basic Books, 1985.

Excellent look at America's space program when it was at its most alive and vital.

McGovern, James. *Crossbow and Overcast.* New York: William Morrow, 1964.

Fast-moving story of the U.S. and British intelligence agencies' efforts to learn more about Germany's V-2 rocket.

Murray, Charles, and Catherine Bly Cox. *Apollo: The Race to the Moon.* New York: Simon and Schuster, 1989.

Classic book on the Apollo program.

Ordway, Frederick I. III and Mitchell R. Sharpe. *The Rocket Team.* Revised with a foreword by Wernher von Braun from the first edition. Burlington, Ontario: Apogee Books Space Series, 1979, 2000.

This revised edition of the 1979 classic includes a two-sided DVD containing nearly five hours of video and visual material—including video footage of von Braun at about 27 years old, overseeing V-2 testing launches at Peenemünde. Also included are several biographical clips, scenes from Fritz Lang's Frau im Mond*, and von Braun giving speeches about rockets in the United States.*

Piszkiewicz, Dennis. *The Nazi Rocketeers: Dreams of Space and Crimes of War.* Mechanicsburg, Penn.: Stackpole Books, 2007.

Piszkiewicz has updated his 1995 book by the same name, now packaged as a paperback. He takes a hard look at von Braun and the other German rocket scientists and abandons the more sympathetic views taken by many historians. He sees a bloody legacy left behind in Germany by von Braun and the rocket team, pointing out how this group of space enthusiasts compromised themselves by trading space rocket development for weapons of mass destruction. Piszkiewicz also holds von Braun and his team responsible for cooperating with the SS in the use of concentration camp slave labor to build rockets.

Reid, R. W. *Tongues of Conscience: Weapons Research and the Scientists' Dilemma.* New York: Walker and Company, 1969.

A probing look at science and the military.

Siddiqi, Asif A. *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974.* Washington, D.C.: National Aeronautics and Space Administration History Division, 2000.

A hefty tome, providing carefully presented facts.

Taylor, Theodore. *Rocket Island.* New York: Avon Books, 1985.

Brief, interesting story of Peenemünde told from the military rather than the technical standpoint. Not much new but easy to read.

Tsiolkovsky, Konstantin E., *Beyond Planet Earth,* translated from the Russian by Kenneth Syers. Originally published in Russian as *Exploration of Space by Rocket Devices* in 1903. New York: Pergamon Press, 1960.

———, *Selected Works,* translated from the Russian by G. Yankovsky. Moscow: Mir Publishers, 1968.

Classic papers and articles by the greatest Russian rocket pioneer.

Winter, Frank H. *Prelude to the Space Age: The Rocket Societies: 1924–1940.* Washington, D.C.: Smithsonian Institution Press, 1983.

Exciting and well-researched look at the men and groups who pioneered the space age.

Wolfe, Tom. *The Right Stuff.* New York: Farrar, Straus and Giroux, 1979. Bantam paperback edition, 1980.

This book is a little slick but it is a classic in space literature.

Wulforst, Harry. *The Rocketmakers: The Dreamers Who Made Space Flight a Reality.* New York: Orion Books, 1990.

Wulforst sets out to write about the adventure of space with the emphasis on the scientists and engineers that made this achievement possible rather than on the astronauts. By weaving together short narrative chapters reflecting many different viewpoints, he has brought his readers into the center of the rocket-making process. The story is both exciting and accessible for all readers.

Books about Germany During Hitler's Regime

Speer, Albert. *Inside The Third Reich.* New York: Macmillan Co.,1970.

Among hundreds of excellent books, this one gives a telling inside view.

Internet Resources

Bryan, Dave. "Remembering Wernher von Braun's German Rocket Team." Associated Press. Posted August 13, 2002. Huntsville, Alabama. SPACE.com. Available online. URL: http://www.space.com/news/spacehistory/vonbraun_020813.html. Accessed June 26, 2007.

Information on von Braun and his rocket team in Germany, based in part on recollections of Walter Jacobi, one of the last remaining technicians of von Braun's team. Additional linked stories: "Walt Disney Helped Wernher von Braun Sell Americans on Space," "Von Braun Team Member Mueller Dies," "Colleagues Recall Space Pioneer Gilruth," and "The Ultimate E-Ticket: Disney World Gets Rocket Fever."

Dr. Wernher von Braun. Redstone Army Military History. U.S. Army, Redstone Arsenal, AL. Available online. URL: http://www.redstone.army.mil/history/vonbraun/welcome.html. Accessed June 26, 2007.

Offers a short biography, a brief chronology, and 13 pages of photographs.

Wernher von Braun. MSFC History Office. The Marshall Space Flight Center (MSFC). Huntsville, Alabama. Available online. URL: http://history.msfc.nasa.gov/vonbraun/index.html. Accessed June 26, 2007.

This Web site has a treasure trove of material, including interviews with von Braun, media clips, and photos.

Williams, Robin. Wernher von Braun (1912–1977). On the Shoulders of Giants. NASA Earth Observatory. Available online. URL: http://earthobservatory.nasa.gov/Library/Giants/vonBraun/. Accessed June 26, 2007.

NASA's Earth Observatory page has a brief biography of von Braun, a nicely drawn portrait sketch (by Roger Kammerer), and a look at his rockets. Additional information available on subsequent pages includes: The Liquid-Fueled Rocket, A Public Firing, Modern Rocketry, and References. Also included: a glossary feature that can be turned on or off.

INDEX

Italic page numbers indicate illustrations

A

A-1 rocket 37
A-2 rocket 37–39, *38*
A-3 rocket 47–48
A-4 rocket 63. *See also* V-2 rocket
  altitude records of 56, 88
  combustion chamber design 50
  cutaway view of *49*
  development of 48–51, 55–57
  specifications for 48
  as terror weapon 69
A-4b rocket 69
A-7 rocket 69
A-9 rocket 69
A-10 rocket 69
Aachen, Germany 51
Aberdeen Proving Grounds, Maryland 82–83
acceleration, effect of 26
Aero-Medical Laboratory 88
"air-breathing" engines 12
air raid, British 59–63
Aldrin, Buzz 121–122
Alexandria, Virginia 130
Alpine Redoubt 76
altitude record
  set by A-4 56
  set by Bumper No. 4 90
  set by two-stage Jupiter rocket 102
amateur rocketry 5
American Museum-Hayden Planetarium 96
American Rocket Society xxi
America's Next Decades in Space: A Report of the Space Task Group (NASA) 127
Anders, William A. 120
animals, effect of radiation on 88
animals, test 101–102
Ankham, Germany 63
Antwerp, Belgium 69
Apollo Command Module 116
Apollo fire 121
Apollo program xviii, 116–123, 133
Apollo-Soyuz 131
Applications Technology Satellite (ATS-6) *129,* 130
Armed Forces High Command 68
Armstrong, Neil 121–123
Army Intelligence Service 82
Army Ordnance Office 55
Army Weapons Office 33
Association for the Utilization of Industrial Gases 34
Atlas rocket 102, 110, 111–112
atomic bomb 70
Auden, W. H. 3
Auschwitz extermination camp 66
automatic pilot 51

B

ballistic missile 47–51, 102
Baltic Sea 43
Baltimore, Maryland 12
Bannasch, Hannelore 61
Barrett, George 104
Bay of Pigs, Cuba 112–113
Becker, Karl 33
Belgium 69
Bell Laboratories 80
Berlin, Germany 2–4
"Black List" 79
Blizna, Poland 63
Bonestell, Chesley 19–20, 96
Borman, Frank 120
Boulogne, France 12
Brand, Vance 131
Brauchitsch, Walther von 54
Braun, Iris Careen von 85, 103

Braun, Magnus von 1, 74, 77, 78
Braun, Margrit Cecile von 85–86
Braun, Maria von 103. *See also* Quistorp, Maria Louise von
Braun, Peter Constantine 86
Braun, Sigismund von 1, 5
Braun, Wernher von *94*
A-4 rocket 55–57
awareness of slave labor 66
with brothers, as child 5
childhood and early education 1–8
death of 131–132
detention by SS 67–68
development of A-4 rocket 48–51
as director, Marshall Space Center *97*
on duty and conscience 137–138
early career in Germany 25–27
education of 18
with Eisenhower *117*
experiments with mice 26–27
FBI files on 86–87
at Fort Bliss, Texas *84*
German army civilian employee 33–34, 40–41
on Hitler 33
in Huntsville, Alabama 91
legacy of 133–136
meets Willy Ley 17–18
with "Mercury Seven" astronauts *113*
move to United States 81–83
relocation of facilities to Mittelwerke 74–77
at rocket launch *116*
signing autographs *96*
and Society for Space Travel members *23*
and Society for Space Travel test site 24–25
as SS officer 70
surrender of *78*
and Tomorrowland theme park xix
and U.S. space program 93–99, 103–104, 111, 126–130
with Walt Disney *xx*
during WWII 61, 66–70, 78–79
British air raid 59–63
British Bomber Command 59
British Interplanetary Society 18
Bumper missile 89–90
"buzz bomb." *See* V-1 rocket

C

Cape Canaveral 91
Carter, Jimmy 132
centrifuge 26, 40–41
Challenger explosion 121, 135
Charlottenburg Technische Hochschule 18
Ciudad Juárez, Mexico 90, 91
Clarke, Arthur C. 66
cold war 99, 109, 113
Collins, Michael 121–122
combustion chamber 50
cooling of 32
description of 35
design of A-4 rocket 50
and fuel injection 36
Command Module 116–118, 120–122
communications, satellite 136
concentration camps 65–66
Congreve, William 10
Congreve rockets 10, 12
Conquest of Space (Ley) 19–20
The Conquest of the Moon (von Braun, Ley, and Whipple) 19
Copenhagen, Denmark 12
countdown 22
Cronkite, Walter 131
Crowther, Bosley 98
cruise missile 46
crystal growth research 135

D

Daimler (Mercedes) Benz 131
Debus, Kurt 121
Dengenkolb, Gerhard 63
Disney, Walt xviii, *xx*, 21, 97–99
Dora concentration camp 65
Dornberger, Walter *30, 39*
A-4 rocket 48, 50, 55–57, 63
in Alps 76

ballistic missile development 48
commands Peenemünde-East 47
contract with Luftwaffe 40
gathers rocket experts 77
Hitler visits 52–54
inspects Peenemünde site 43
makes case for Peenemünde 45
Peenemünde air raid 60–62
replaced by Storch 74
rocket development 30–37
secures von Braun's release from SS 68–69
seeks rocket development site 41
and SS 64–65
supported by von Braun 67
war criminal charges 80

E

East Germany 80
Ehricke, Krafft 56
Einstein, Albert 4, 25, 70
Eisenhower, Dwight D.
approves *Explorer 1* satellite launch 107
creates NASA 110
orders German scientists to United States 81–82
response to *Sputnik* 104
transfers von Braun to NASA 111
with von Braun *117*
Electromechanical Works 74
England 69
Ettersburg Castle boarding school 6
"Exploration of Space by Rocket Devices" (Tsiolkovsky) 13
Explorer 1 (satellite) 107, 109

F

FBI files on von Braun 86–87
Faget, Max 110
Fairchild Industries 130
Fieseler Fi-103. *See* V-1 rocket
"fire arrows" 9
Fletcher, James C. 130
Ford, Gerald R. 131
Fort Bliss, Texas 81, 83–85
Fort McHenry 12
France 69
Frau im Mond (film) xvii, 19, 21–22
Freedom space station 136
Friedland, Germany 63
Fritsch, Wernher von 45, 48
fuel injector 36, 50
fuel mixture 50
fuel pump 50

G

Gagarin, Yuri 112
Gemini program 116, 118
General Electric Company 84, 128
Generales, Constantin 25–27
George C. Marshall Space Flight Center 97, 111
German Air Ministry 41
German army 29, 30–33, 45–47
German rocket scientists
and British 80
legal status of 90
relocation to Huntsville, Alabama 91
and Soviet Union 79–80
and United States 78–81
Germantown, Maryland 130
Gestapo 39–40, 52, 67, 68
Glenn, John 112
Goddard, Robert xviii, *14*, 14–15
Great Britain
and German rocket scientists 80
Greifswalder Oie Island 47–48
Grissom, Gus 112
Gröttrup, Hermann 68, 79
Grünow, Heinrich 34–36
Guggenheim, Harry D. *14*
Guggenheim Foundation 14
guidance system 37, 55
gyroscope 37, 45

H

Haber, Heinz 98
Haidar Ali 10
Halifax heavy bombers 59
Hamill, James P. 83, 85

Ham the chimpanzee 112
Harz Mountains 65
Heinkel He-111 bombers 51
Hermann, Rudolph 51
Hermes program 84, 88
Hero of Alexandria 11
Himmler, Heinrich
  increases SS control 74
  proposes SS takeover 66–67
  and secrecy of A-4 project 64–65
Hindemith, Paul 2
Hiroshima, Japan 70
Hitler, Adolf
  Alpine Redoubt scheme 76
  von Braun on 33
  concern for secrecy 64
  rise to power 39
  "scorched earth" policy 75–76
  sees A-4 as "miracle weapon" 63
  suicide of 78
  support for rocket development 54–58
  V-2 as secret weapon of xviii
  visit to Kummersdorf *51,* 51–54
Holocaust xxi
Houston, Texas 111, 123
human physiology
  effect of space travel on 25–26
Hunt, Linda 86
Huntsville, Alabama
  and von Braun 125–126
  description of 103
  relocation of German rocket scientists to 91
Huzel, Dieter 76, 77, 111
hydrogen peroxide/permanganate pump 50

I

I Aim at the Stars (film) 98
ICBM (Stine) 131
incendiary rockets 9
India 10, 130
Institute of Technology, Zurich 25
intercontinental ballistic missiles (ICBMs) 47, 102
intermediate range missiles 102
International Space Station *128*
interservice rivalry, German 45
Isherwood, Christopher 3

J

jet engines 12
jet-propulsion principle 11–12
Jews xxi, 39, 52
Johnson Space Center 111
Jupiter-C rocket 107
Jupiter missile 102
Jupiter rocket 102
Jurgens, Kurt (Curd Jürgens) 98

K

Kaltenbrunner, Hans 68
Kammler, Hans 64–65, 74–77
Keitel, Wilhelm 68
Kennedy, John F. 112–113, 115
Kennedy Space Center 120, 131
Kesselring, Albert 45–46
Kubasov, Valery 131
Kummersdorf, Germany
  A-3 rocket development at 47–48
  engine work at 50
  as experimental rocket station 30–32
  rocket testing at 34–38
  visit of Hitler to 51–54
  visit of von Fritsch to 45

L

Lancaster bombers 59
Lang, Fritz xvii, 21–22
Langley Research Center 110
launch vehicle. *See* rocket
League of Nations 40
Leonov, Alexei 131
Ley, Willy *18*
  biography of 19–20
  consults on *Frau im Mond* (film) xvii
  flees Germany 70
  influence of Oberth on 15
  introduces von Braun to Oberth 23
  meets von Braun 17–18
  sets up rocket test site with VfR 24
  and Tomorrowland TV show xix
  work with Disney 98

Lindbergh, Charles *14*
liquid-fuel rocket
A-1 design 37
demonstration to von Fritsch 45
first reliable 50
first successful 14–15
Kummersdorf experiments 34–36
living in space 134
London, England 69
Lovell, James A., Jr. 120
Luftwaffe 40–41, 45–47
lunar landing 110, 113, 121–124. *See* Moon landing
Lunar Module 116, 117–118, 120

M

Manned Space Flight Center 111
The Mars Project (von Braun) 95
Mars voyage program 127–129
McElroy, Neil 104
Medaris, John 104
medical research 26, 88, 135
Mercury program 110–113
"Mercury Seven" astronauts *113*
"Method for Reaching Extreme Altitudes, A" (Goddard) 14
Mirak II rocket 31–32
Mirak I rocket *23*
Mir space station 134, 136
missile. *See also* rocket
missile, ballistic 47–51
missile, cruise 46
Mittelwerke rocket factory
von Braun and 70
capture by U.S. Army 77
conditions in 65–66
Moon landing 113
Apollo mission 121–124
Kennedy proposes as goal 113
Space Task Group discussion of 110
motion, third law of 11
multistage rocket 69, 89–90
Mysore army 10

N

Nagasaki, Japan 70
National Advisory Commission for Aeronautics (NACA) 110
National Aeronautics and Space Administration (NASA) 110, 126–130
National Medal of Science 131
National Space Institute (NSI) 130
National Space Society 130
Nazi Party
von Braun membership in xxi, 70, 86–87
censorship of Willy Ley 19
effect on von Braun's U.S. career 126
rise of 39–40
Nebel, Rudolf
assists Oberth 21–24
with von Braun, carrying rockets *24*
founder of Society for Space Travel xvii
influence of Oberth on 15
opposition to military work 33
with Society for Space Travel members *23*
Newton, Isaac 11
Next Decade in Space, The (President's Science Advisory Committee) 127
Nixon, Richard 127, 128–129
Nordhausen, Germany 65
Nordhausen concentration camp 65, 76, 87
nozzle, rocket 50

O

Oberammergau, Germany 76
Oberjoch, Germany 77
Oberth, Hermann *22*
movie consultant xvii, 19
publishes book 15
rocket construction of 21–24
with Society for Space Travel members *23*
space travel theories of 7
with Walter R. Dornberger *30*

Oder River 43
Operation Paperclip xxi, 79–80
Oppenheimer, Robert 70
orbital spaceflight 112

P

Paine, Thomas O. 127, 128
Paris Gun 12, 56
Peenemünde rocket development center xx, 44*m*
  British air raid on 59–63
  construction of 43–47
  evacuation of 74–76
  transfer of work from Kummersdorf 54
Peene River 43, 45
Pioneer probe 107, 134
Polaris rocket 102
Polizei Präsidium 67
Post-Apollo Space Program: Directions for the Future, The (Space Task Group) 127
President's Science Advisory Committee 127
prisoner labor 65–66
"Project Adam" 110
"Project Blossom" 88
pump, fuel 50

Q

Quistorp, Emmy von 1
Quistorp, Maria Louise von 85. *See also* Braun, Maria von

R

radiation, effect on animals 88
radiation belts 109
Raketenflugplatz (rocket airfield) 24–25, 29–30
Randow River 43
range
  of Paris Gun 12
  of projected multi-stage rocket 69
  of V-2 71
recoil 10
Redstone Arsenal
  von Braun at 96
  intermediate-range missile development at 102
  Jupiter-C missile built at 107
  transfer of von Braun from 111
Redstone rocket 102, 112
redundancy principle xviii, 120–121
reentry 110–111
Reichstag fire 39
Reichswehr 29, 45. *See also* German army
Reinickendorf, Germany 24, 29
Reitsch, Hanna 51, 60
Riedel, Klaus *23*, 68
Riedel, Walter 34–36, 39
rocket. *See also specific rocket, e.g.* Saturn V
  aerodynamic design of 50–51
  history of 9–13
  incendiary 9
  principles of 11–12
  "single stick" 31
  sounding 89
  static engine testing 35–36
  theory 13
  as weapon 10, 12–13
rocket-assisted takeoff 41, 45
"Rocket City." *See* Huntsville, Alabama
rocket engines 12
  combustion chamber design 32
  design improvements 50
  overheating of 31–32
  Saturn V *117*
  static testing of 35–36
  work at Kummersdorf 50
Rocket into Interplanetary Space, The (Oberth) 6–7, 15
rocket nozzle 50
rocket-powered aircraft 40–41
rocket-powered plane 60
Rockets, Missiles, and Space Travel (Ley) 19
rocket testing at Kummersdorf, Germany *38*
Royal Air Force 59–60
Royal Marine Artillery 10
Rudolph, Arthur
  accused of war crimes 87
  interest in space travel 37–38
  proposal for rocket development base 41
  on rocket building team 34, 36
  successful A-2 launch 39

S

Sadelkow, Germany 63
satellite communications 136
Satellites, Rockets, and Outer Space (Ley) 17

Saturn 1B 131
Saturn I 118
Saturn V rocket
Apollo 11 launch 121–122
development of 118–120
diagram of *119*
launch of Skylab 134
rocket engine *117*
role of Arthur Rudolph in 87
significance of 136
specifications of 115
Schleicher, Kurt von 39
Schumann, Erich 33
science fiction 4
Searby, J. H. 59
secret police. *See* Gestapo
Sheldon, Charles S. 126
Shepard, Alan 112
Shows, Charles xix
Silesia 1, 41
"single stick" rocket 31
Skylab 134
slave labor 65–66
Slayton, Deke 131
Smithsonian Institution 14
Society for Space Travel (VfR)
builds rocket test site 24–25
contract with German army 31–32
demonstration for German army 29–31
founding of 18, 21
Ley as founder and spokesman of 19
members group *23*
rocket development disbanded 33–34
significance of xvii–xviii
solid-fuel rockets 14, 31
sounding rocket 89
Soviet Union
ballistic missile program 93
and German rocket scientists 79–80
space program of 101–102
and space race 109–110
Soyuz spacecraft 131
spacecraft design 116
spacecraft sketch *7*
spaceflight, orbital 112
space living 134
space race 101–102, 109–110, 134
Space Shuttle 134–135
space stations
Freedom space station 136
International Space Station *128*
Mir space station 134
Skylab 134
Space Task Group 110, 127
Space Transportation System. *See* Space Shuttle
space travel
effect of radiation 88
effect on human physiology 25–26
effect on test animals 101–102, 112
speed formula 13
Speer, Albert 69
appoints production engineer 63
in charge of Peenemünde completion 54–55
promotes A-4 as weapon 57
protests SS infringement 74
Sputnik (satellite) 101–102, 104, 109
Sputnik 2 (satellite) 101–102
SS (Schutzstaffel) xxi
in charge of rocket construction 64–65
detains Wernher von Braun 67–69
effort to take over Peenemünde 66–67
formation of 39
response to Soviet advance 73–74
von Braun officer in 70, 86
stability
A-3 crashes 48
balance of rocket 39
and crash of Mirak II rocket 32
initial failure on A-4 55
and rocket spin 37
stabilizing stick 32
Stafford, Frank Thomas 131
static testing 35–36, 45
Stehling, Kurt R. 105–106
Steinhoff, Ernst 61, 77
Stettin, Germany 67
Stettin Lagoon 43
Stine, Harry 131
Storch, Paul 74
Stuhlinger, Ernst 85, 98, 125–126
Sun, orbit of 107
supersonic speeds 50–51
Surveyor program 110

T

targets, of V-2 rocket 69
technical drawings, of V-2 rocket 76

Technical University, Aachen 51
Tessman, Bernhard 76, 77
test animals 112
theory, rocket 13
Thiel, Walter 50, 62
third law of motion 11
Thor rocket 102
Tipoo Sultan 10
Titan rocket 102
Toftoy, Holger N. "Ludy" 79–81, 85, 89
Tomorrowland theme park xix
"translunar injection" 120
Travel in Outer Space (Ley) 19
Treaty of Versailles 3, 30, 34
Tsiolkovsky, Konstantin Eduardovitch 13
two-stage rocket development 89–90

U

Uecker River 43
Uhl, Edward G. 131
United States
  and German rocket scientists 78–81
University of Berlin 33
Upper Atmosphere Research Panel 88
U.S. Air Force Air Materiel Command 88
U.S. Army 76
  advance into Germany 76
  capture of Mittelwerke rocket factory 77
  and German rocket scientists 78–81
  missile program 97
  Redstone Arsenal 102, 111
  rocket development unit 83
U.S. Army Ordnance Corps 83
U.S. Navy 104–107
Usedom Island 41, 43

V

V-1 rocket 46, 69
V-2 rocket. *See also* A-4 rocket
  effectiveness of 69
  pressure to increase range 73
  range of 71
  as secret weapon xviii
  technical drawings of 76
  use in Hermes project 84–85, 88
Van Allen belts 109
Vanguard project 104–107
"vengeance weapons" 69–70
Verne, Jules 4
Versailles, Treaty of 3, 30, 40
VfR. *See* Society for Space Travel
Voyager probe 134

W

WAC-Corporal sounding rocket 89
war crimes 87
Washington, D.C. 126
Wehrmacht. *See also* German army
weightlessness research 135
Weimar Republic 3
Wells, H. G. 4
Whipple, Fred 19
White Sands Proving Ground, New Mexico 81, 85, 90
wind tunnel 50–51, 63
Wirsitz, East Prussia 1
Wolf Hirth's Soaring School 40
Wollin Island 43
World War I 2–3, 12, 52
World War II 54–79
Wyrzysk, Poland 1

X

X-15 rocket plane 88

Z

Zanssen, Leo 64